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OF

Physical Tests

AND

Laboratory Practice.

A résumé of Practical Tests made in the Laboratories of the World.

EDITED BY H. M. NORRIS.

PUBLISHED QUARTERLY

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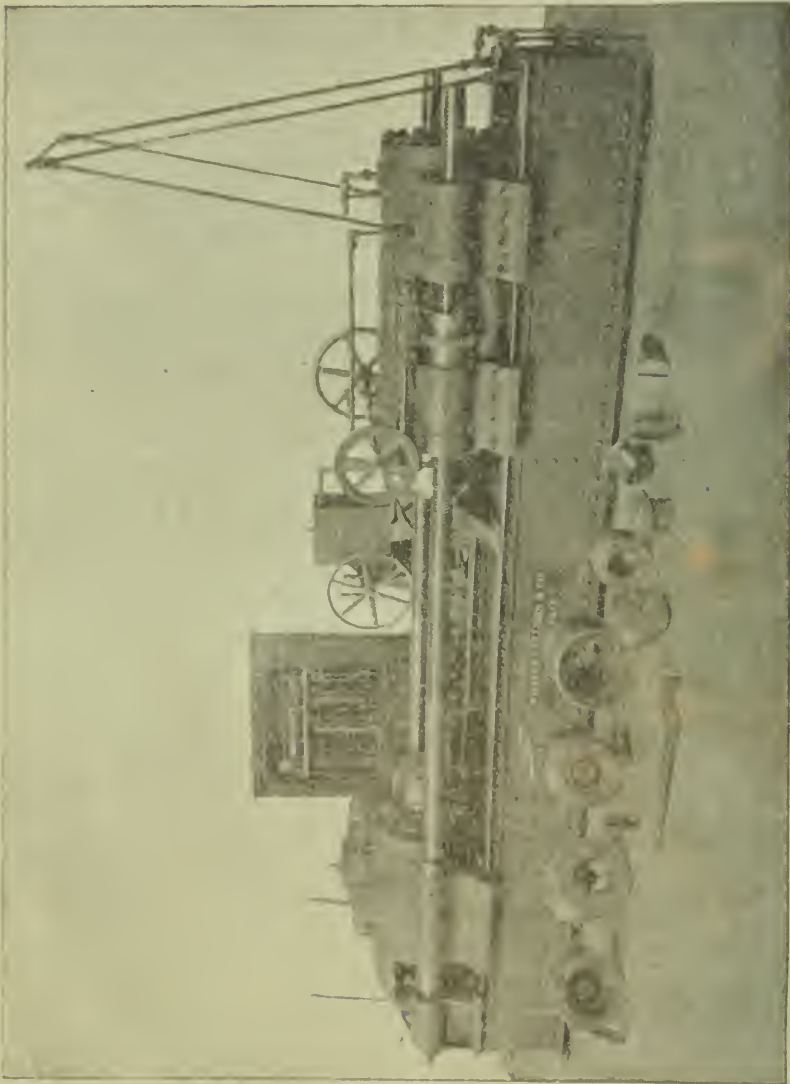

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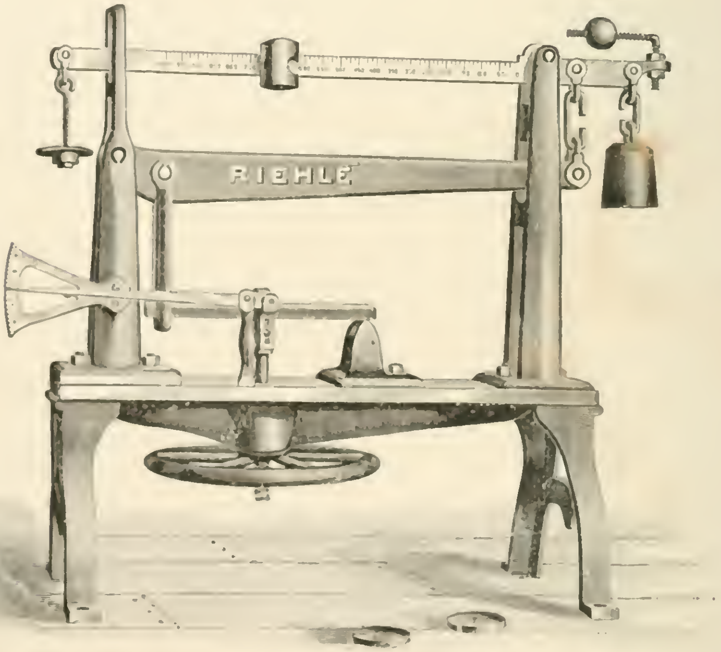

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Digest of Physical Tests.

A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE LABORATORIES OF THE WORLD.

Vol. I. **APRIL, 1896.** **No. 2.**

SCIENTIFIC TIMBER TESTING.

By B. E. Fernow, Chief of Division of Forestry, Department of Agriculture.

IT is a remarkable fact that although wood has been, through all ages, and continues to be the most widely used building material, less definite knowledge is to be found regarding its behavior, its strength, and the factors which influence these than regarding any other material. Timber testing, to be sure, has been carried on as long as any testing of materials, but the results of such testing have mostly remained unsatisfactory, because the testing was not carried on by scientific methods.

There are two reasons for this deficiency: While all other materials are more or less homogeneous, being manufactured by man, and capable, therefore, of being produced under nearly uniform and known conditions, and with nearly uniform results, wood, the product of nature, is most non-homogeneous, and being produced under constantly varying conditions, a result of many changing seasons, it is most variable in its structure, quality, and behavior. In fact, while we may say that with materials like iron, brick, cement, and even stone, we test the material, with wood we test a complicated structure of ever-varying design. While the difficulty, therefore, of arriving at satisfactory data for general application is great, the other reason for our deficiency in them comes from the fact that most of the testing done in the past has been done by engineers who were not at the same time botanists, or rather physiologists, and who failed to study and to appreciate, or to allow for the variability of this fickle material. Not only is it necessary to distinguish between the many different species—engineers are rarely capable of recognizing more than the genus, if one may judge from the engineers' tables of strength, in which mostly generic names only, spruce, fir, pine, oak, etc., are used—but one must know also to distinguish differences in development of the species, and take into consideration physical as well as chemical properties of wood.

I would make, therefore, this first postulate for the successful timber-tester, that he be not only an engineer but a botanist at the same time, or else have a botanist, a man conversant with vegetable physiology, at his elbow. There are not even many botanists who know enough of the physical properties and the behavior of wood to be able to fill the position. To be a successful tester of timber, the rare combination of engineer, botanist, and physicist, an expert in "timber physics," is required.

Although Muschenbroek and Buffon and Duhamel de Monceau, in the last century, carried on timber tests with some regard to the various influences upon strength, coming apparently to contradictory results, while Barlow and Dupin, early in this century, Poncelet, Hodgkinson, Paccinoti, and Peri later did good service in working out experimentally the mathematical side, the first time that such a combination of naturalist and technicist was nearly attained, was when the two Frenchmen, Chevandier and Wertheim, the one an engineer, the other a forester, undertook in the fifth decade to subject the timbers of France to a comprehensive investigation, with due regard to proper rules of inspection of the test material, publishing their results in 1848. But although many valuable truths were established by these men and those following their methods, among their number Tetmayer and Bauschinger, the highest authorities on timber testing at present, the subject has not by any means been exhausted, and when it comes to American timbers we can, without invidiousness, say that none of the tests that have been made until very recently were carried on with the precautions and inspection of the material that make them conclusive or practically applicable.

WHAT ARE TESTS MADE FOR?

There are two objects to be subserved in testing of any kind of materials, and we may divide the testing accordingly into two classes. The one, which we may call *commercial* testing, has in view to find out the relative value for a given purpose, of a given lot of materials offered in market or presently to be applied; it does not inquire into the properties in general, their variations due to different causes, or into the reasons for such variation. The other kind of testing, which we may call *scientific* testing, has in view to find out what the capabilities of materials are, what causes the properties, how they are related to each other, and how they may be produced or influenced; it attempts to develop *laws* of strength and to furnish data for *general* application.

The first kind of testing simply records the *usage* of the practice, the second lays the foundation for the *improvement* of the practice. From a lot of iron or steel to be used in a bridge some sample pieces are broken, to assure the engineer that the rest of the lot is capable of sustaining a given load: this is commercial testing, the result of which is simply to state that the present lot of iron is of a given quality in the average, satisfactory for our present purpose, but it does not allow us to judge from this to another lot of iron, manufactured elsewhere under different conditions. In fact, unless we are sure that all the material was made and treated alike, and that the samples represented it fairly, we know hardly more than what we learned of the sample pieces themselves.

From the same lot the manufacturer takes samples, tests them for their strength, and examines them carefully as to structure and chemical analysis, the appearance of the fracture, the behavior during the test, and considers these data, together with the manner in which he had produced this material, and perhaps compares all these data with similar data obtained from another lot of material. This is scientific testing, which furnishes us a general judgment as to the qualities of the material under varying conditions and appearances, and leads, for the practitioner, to *rules of inspection* and to improved methods of manufacture or application.

So well is it understood that commercial testing is an insufficient assurance of the quality of a lot of iron or steel that in important work, bridge construction, for instance, inspectors are constantly present during the manufacture of the material to assure themselves that the stipulated ingredients enter into the material, and that it receives a stipulated treatment; and no engineers' tables are considered satisfactory by themselves. Yet there has been developed for this class of materials a tolerably reliable set of rules for inspection, so that by physical examination an approximation to the quality and behavior of the material can be diagnosed. Not so for timber. Most tests that have been carried on in our mechanical laboratories have been done in this wise: Material has been secured from a wood-yard under the name given by the yard man, who notoriously mixes various species together and cannot distinguish them; no attempt is made to make sure of the species; in fact, the means for doing so are usually not at the command of the professor; no knowledge as to the conditions under which the material has grown exists, or from what part of the tree it comes; no knowledge as to how it has been treated after felling; no careful examination as to the moisture it contains, although this factor alone, it is known, influences strength to an extent of sometimes more than 50 per cent.; no examination as to its position in the tree with reference to the grain, nor of the character of its structure, its specific gravity. In short, the whole performance is more or less blind.

From what has been said regarding the great variability of wood, we may at once discard the idea that our knowledge will be increased appreciably by a continuance of the methods of breaking sticks, large or small, indiscriminately, without knowledge as to what they really are. Commercial testing, as we have called it, may satisfy the consumer in a special case, but it does not furnish general knowledge; it does not permit of general application with any degree of reliability. In fact, commercial testing with so variable material as wood is hardly of use until we have also data of inspection, derived from systematic series of tests, which allow us to compare the tested material with that of which the test piece was supposed to be a sample, and to gauge how far the sample represents the average, or how far above or below the quality of the untested material may fall; in other words, until scientific testing enables us to interpret its results. Nay, I may go so far as to say that when by a systematic series of wood testing data for inspection have been established, commercial testing will become unnecessary, the mere inspection of the material furnishing much more reliable results.

For such data of inspection we must have recourse to what we have called scientific testing, which consists in a methodical, systematic procedure, planned with circumspection and carried out consistently on testing material selected with careful reference to all conditions that may have an effect on its quality and behavior. Scientific experiment in general consists in analyzing first the variables which contribute toward a complex total effect, and then by eliminating as many as possible of the variables determine the effect of any one or of any one set of variables in various combinations. They are designed not to show what the practitioner is doing, but to explain the phenomena in the practice and thereby to improve the practice.

The first requisite of course is that we should know what the material is we are testing. This seems axiomatic, and yet, as we have stated before, most experimenters have known but imperfectly the nature of their specimens. If, for instance, we wish to establish the value of the species known as Longleaf Pine, we must make sure that it is Longleaf Pine which we are testing. This cannot be done by selecting from a wood-yard, for we have so far not even any means of distinguishing its wood with certainty, and other species are easily mixed in, hence we must have the material selected in the woods by a botanist who by foliage and fruit can make sure that the tree belongs to the species sought.

As a matter of more indirect interest rather than for rules of inspection, it is desirable to note the exact conditions of soil, climate, and surroundings, such as may influence the quality of the tree, and the part of the tree from which the test material is taken. For this knowledge may give us an indication as to what to expect from given growth conditions, and assist us later in selecting for different purposes the various cuts, which may differ by fully 25 per cent. in their strength.

The next point to observe is the treatment of the material after felling: the manner in which the seasoning is done. Due to the non-homogeneous arrangement of the various parts of the log or stick, the contraction due to the loss of water from the cell walls, which make up the wood structure, is uneven, and gives rise to "season checks" invariably. These are always by necessity sources of weakness, even though closing up again, by swelling due to water absorption or re-arrangement of parts. This variable is impossible to eliminate, and so difficult to take into account that all the experimenter may do is to reduce its occurrence to the smallest extent possible by careful attention to the seasoning process.

The next care is in the shaping of the test stick. This is usually done by sawing and with little reference to resulting relations of the structural aggregates which make up the stick. In the first place, the fact that most trees do not lay on their annual growth in straight up-and-down arrangement of cell elements, but form a more or less spiral growth, which if cut with reference to the direction of the mathematical axis results in cross-grain of varying degree, points to the necessity of splitting the wood, which gives more assurance of reducing this variable. If sawing is adhered to, the existence of cross-grained condition must at least not be lost sight of in interpreting results. In the next place, attention must be paid to the lay of the annual rings with reference to the cut. The tree being built up by a series of superimposed hollow cones or rather neloid-shaped bodies of wood, a cut parallel to the axis produces sticks containing different sets of structural aggregates according to the location of the cut with reference to the radical plane, as will be readily understood by reference to the figure.* In each case the combination of structural aggregrates, cones and cone sections, varies and gives rise to difference in strength of the combination; hence whether the stick is cut quarter sawed or rift-sawed, or bastard sawed, makes all the difference in its behavior.

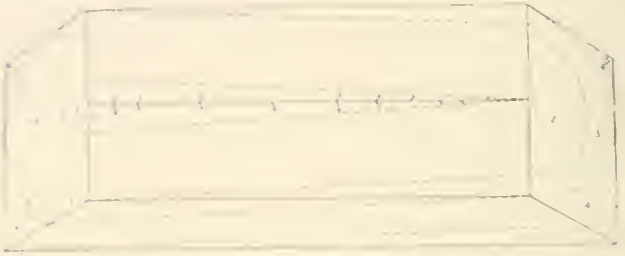

Fig. 1.—A piece of sawn timber cut through along the pith, illustrating its structural aggregates.

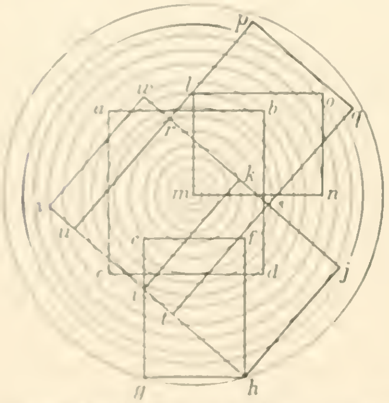

Fig. 2.—Possibilities of cutting timber from a log with reference to position of grain.

Having now secured a test stick with knowledge of its species, its derivation, its position in the tree, and its structural aggregates, at least three further facts must be ascertained—the character of its growth, its moisture contents, and its specific weight. In the species which have a distinct ring growth, like the pines, oaks, etc., in which each ring contains two classes of wood—namely, springwood and summerwood, the one loose or porous, the other made up of dense, thick-walled cells—the proportion of each of these predicates the strength and the weight of the seasoned wood is naturally also predicated by the proportion of these two elements of the annual ring. This feature alone—not the width of the ring, but the proportion of the summerwood and springwood forming the ring—is perhaps the most reliable criterion for an inspection and qualitative determination of the material.

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* Kindly loaned by the U. S. Department of Agriculture.

One of the most difficult of all the variables to take care of and yet one of the most important and the most variable one is the moisture contents. Often more than half the weight of freshly-felled timber is due to water, which is partly contained in the cell lumina, partly in the cell walls. In seasoning this water is lost; at first, while the lumen furnishes the supply for the evaporation readily, then more and more slowly, and such is the hygroscopicity of wood that it never parts with all the water, but retains, varying with the temperature and moisture conditions of the atmosphere in which it is kept, from eight to twelve and more per cent. From the point when the cell wall begins to lose water, which for pine, for instance, may be roughly placed at 35 per cent. of the weight of the dry wood, with the loss of water the strength is increasing rapidly, so that the same stick may show when dried to 10 per cent. a strength 50 per cent. greater than in the unseasoned condition. It is therefore of greatest importance to know the moisture per cent. of the test piece and the rate of variation with the loss of water.

The methods for ascertaining the moisture per cent. so far employed are still unsatisfactory, especially when it is considered that the moisture is not evenly distributed through the stick; the determination by borings practiced by Bauschinger, and even the disk method employed in the Division of Forestry do not quite satisfy the requirements of desirable exactitude; hardly anything short of repeated weighings and drying of the test piece itself will be reliable.

That all pieces containing knots and other defects must be excluded from a series which is to establish the standard value of the species—except when the effect of such defects is to be tested—seems self-evident. We may also take for granted as an essential requisite true workmanship in shaping the test piece. Lastly, the position of the grain, with reference to the load in the test, is an essential point that must not be forgotten, for according to this relation of load to structure different values will be obtained, a matter in which wood differs from iron or steel.

Finally, a word as to the size of the test pieces: Practical engineers have clamored for tests on large sizes such as are used in practice, claiming that tests on small selected pieces do not give data applicable in practice. This is an erroneous position, provided the tests which are to furnish the standard are made in large number, and with such precaution, and under such rules of inspection as stated whereby the data become applicable to any case. It is true that larger sizes are apt to behave differently, although not always and not necessarily, from smaller sizes for good reasons; but even Prof. Lanza, who has attempted to establish the numerical difference in the value of tests on large and small sizes has failed to explain the cause of the difference fully, and failed especially to give us such data regarding his test material as will allow us to inspect the material and apply his coefficients to any other material than that tested.

In large timbers not only is the chance for defects increased, but the variables above referred to become more complex and less controllable, while the relation of structural aggregates, as explained before, allows of greatest variety; especially the degree of seasoning, varying greatly in their various parts, withdraws itself from control. They are, therefore, not fit for the purpose of establishing reliable standard data, for such only select material of quality and condition, as thoroughly known as possible, is permissible, and of sizes which, while large enough to secure a sufficiently high per cent. of accuracy, avoid as much as possible the difficulties mentioned in regard to defects, cross grain, uneven seasoning, etc. It then becomes the subject of special investigation to determine the effect of each of the variables, and, finally, it may be desirable to investigate directly the effect of their combination as found in large sizes by analysis of the tested columns and beams themselves.

I hear some "practical" engineer say that in practice it would be impossible to apply such refined knowledge, and hence the test data should refer to conditions only which occur or are usual and recognizable in actual practice.

To such my answer can here only be brief. This paper is not written for them; they need some instruction in the history and philosophy of scientific work as applied to practical results, when they will learn that progress, improvement of the practice, can be expected only from applying the opposite of their practical methods. The more refined, the more careful and systematic the methods by which a scientific investigation is carried on, the more likely will it produce results useful to the practice. The conditions, which in the scientific work we analyze and take separate account of, occur in the practice in ever-varying combination. As in chemical and electrical arts, the skillful practitioner must and will learn to disintegrate them, and with the aid of the data furnished by scientific standards make the necessary allowances.

The Division of Forestry has entered upon a series of tests and investigations in timber physics carried on with the precautions outlined for the purpose of determining not only more thoroughly the range of values for our various species but especially of determining the effect of the variables affecting strength and furnishing rules of inspection. The work has progressed slowly on account of deficient funds. During the last four years, however, over 30,000 tests have been made with thorough examination of the test material, and at least for the four Southern pines the data based on over 18,000 tests are already well established.

SYSTEMATIC INSPECTION OF MATERIAL.

By L. S. Randolph, Professor of Mechanical Engineering, Virginia Agricultural and Mechanical College, Blacksburg, Va.

IT would seem that it ought to be completely superfluous to tell a man that it was advisable for him to know what he was buying, or that it would pay him to ascertain whether or not he was getting full value for his money. It will require but a very superficial observation, however, to show that the contrary is the case, and that it will be necessary not only to tell him, but in many cases the most convincing arguments will be ineffectual.

The facility with which all classes of nostrums are foisted on the community, and the difficulty of obtaining reliable material go to show that very few realize the necessity of knowing when the material they buy is what it should be.

No more valuable move has been made, of recent years, by our railroads, then a recognition of the fact that it was necessary to know accurately the character of the material they were using, both in track and rolling stock; so that at the present time all first-class roads either have a testing bureau, as a special department of their own organization, or employ one of the numerous testing bureaus.

The fact that the leading engineers have, for years, required careful and systematic tests of material on all important work, that on the Continent testing bureaus have been established under governmental supervision, and the number of independent testing bureaus in this country, proves the practical necessity for the systematic examination and testing of the materials of construction.

This demand comes from two quarters: 1st. The necessity of protecting human beings from injury or death. 2d. The necessity, especially at the present time, for practicing the utmost economy.

It is scarcely necessary to discuss, or to advance arguments, to prove the necessity for taking every precaution, to prevent the injury or death of a human being. Whilst this has been treated as an economic problem more than once, that phase need scarcely be discussed here, for its value as a factor in the design of any structure will depend entirely upon the moral condition of those in charge of the work.

The value of systematic testing, from an economic standpoint, however, is open to fuller discussion, and brings up more interesting questions.

In conversation with an engineer the other day on this subject, he told me that he was satisfied that he had been compelled, recently, to use from 15 to 20 per cent. more material in a building than was necessary, on account of the impossibility of having the material carefully tested, and this in face of the fact that especially good prices had been paid for it. The saving on a few such buildings would have equipped a testing laboratory.

In a recent investigation of the strength of cements, a sample of cement, which sold for $5 per barrel, when mixed with one-half sand, showed a greater tensile strength than did a sample of another cement selling for $3.50 per barrel, when used neat; and yet enormous quantities of this cheap cement are used.

The author has again and again seen lubricants sold to private consumers, under some high-sounding name, at from 50 to 75 cents a gallon, which were nothing but plain petroleum products, worth, probably, at the most, 20 cents per gallon. One cannot blame an oil salesman for taking advantage of such a snap, but it is rather hard on the man who foots the bills. A considerable portion of the lubricants sold to small consumers are not worth one-half what is paid for them. In fact, it may be taken as a rule that in every branch of trade more or less chicanery and fraud are deliberately practiced, the only safeguard against which is the careful examination of the material.

But it will be argued that one can deal with honest manufacturers only. While it is unquestionably good policy to have no dealings whatever with dishonest parties, yet this does not remedy the matter.

A manufacturer or dealer may be as honest as possible, but that does not prevent his employees from making mistakes, or from willfully shipping defective material to cover their own errors. We might, perhaps, locate dishonest dealers, but it would be impossible to locate the ignorant, careless, or dishonest employee.

The amount of material with defects, which it is inconceivable that any sane person could fail to see, which is shipped by the most reputable concerns proves that the honesty of the head of a concern does not insure the honesty of his subordinates, although it may go a long way toward it.

We have, therefore, to avoid not only the dishonesty of the manufacturers, but also the dishonesty and carelessness and ignorance of their subordinates.

In a steel mill a forging may be piped; if carefully plugged, the chances are that nothing will be heard of it until the failure of the forging reveals the hidden flaw; too late, however, to trace it back and place the responsibility where it belongs.

It has been held, and by the majority, believed, that it is necessary to have inspected and tested the materials used on only the more important structures, such as bridges, office buildings, etc., where there is danger to life or limb of the occupants. While it is undeniably true that such material should be inspected, it is also true that, as a rule, greater economies can be effected by inspecting other kinds of materials, where the results of the failure are not so dangerous to human life and consequently not so disastrous to the reputation of the manufacturer.

The very fact that in most instances the other kinds of material are purchased without any examination at all, gives an invitation to all kinds of fraudulent practices. There is an extensive trade in certain materials, which are used for adulteration alone.

In an investigation, made by the writer of different brands of white lead, only two out of six samples were found to be worthy of the name of white lead; three being utterly worthless.

Upon one occasion, a shipment of lard oil received by the writer was found to contain a large portion of paraffine oil; it was returned, and a second shipment replacing it was also returned for the same cause. At last a shipment of oil was received which was satisfactory. When asked why they shipped such defective material, the reply was that they did not expect it to be so rigidly inspected.

That the rigid examination of materials, which are now received without inspection, is desirable, can scarcely be denied, but how far it should be carried and to what extent it would be economical, is another and a more difficult question to solve. It is evident that it would be advisable, if practical, to have everything tested and inspected, but throwing aside this utopian idea, we can readily see that the systematic inspection of material can be extended far beyond its present limited sphere, with very beneficial results.

As an illustration of what can be done by such inspection, we can find no better example than the results obtained from the inspection of fertilizers. At one time fertilizers were sold entirely on the makers' guarantee or statement; now, in nearly all States some system of fertilizer control is in force, whereby all fertilizers sold in the State, are subject to inspection and analysis, and in some States any citizen can send a sample of fertilizer to the State Chemist, have it analyzed, and an estimate of its value, per ton, placed upon it.

The result of this system of fertilizer control has been not only a marked improvement in the value of the fertilizer actually sold, but, what is of far more importance, the introduction of a condition of affairs which renders the sale of worthless fertilizers practically impossible.

Similar benefits can unquestionably be obtained from an extension of this system to other materials, such as iron, steel, cast iron, oils, paints, and soaps. At present it is very difficult to get a paint which is worth anything, or a good lubricating oil at a reasonable price, and many of the soaps sold throughout the country are so injurious to clothes as to be worse than useless. Is this not, after all, a matter for governmental control? It may be claimed that this is too much like paternalism, but it is unquestionably the duty of the Government to detect and punish fraud wherever found, and there is considerable room here for the exercise of this function. Have not all classes as much right for protection against fraud as the Agricultural, if that class would not be the principal beneficiaries of government inspection?

A NEW TRANSMISSION DYNAMOMETER.

By S. W. Robinson, Professor of Mechanical Engineering, Ohio State University.

IN designing and equipping a machine shop, or, in fact, a manufacturing establishment of any kind, one of the first problems met with, as touching economy and efficiency, is the amount of power required to run the plant. In olden times when the teeth of gear wheels were chipped and filed, and engine cylinders were bored by pushing a hand tool along a plank, this expense was either boldly guessed at, or roughly estimated according to the number of men employed, one horse-power, for instance, being considered sufficient to drive a suitable number of machine tools to keep ten men at work. In modern times, however, where every possible leakage must be looked to with the greatest care, it is not only desirable, but absolutely essential to the welfare of the concern that an accurate knowledge should be had of the amount of power developed by the motor, and the amount required to drive each machine.

The only satisfactory method of ascertaining these quantities is by the use of some form of dynamometer—by which we mean an instrument or machine for measuring the power exerted by an engine or electro-motor, or the amount of power consumed in driving a single machine or machinery plant. A Dynamometer is primarily an instrument to measure the work done by an effort of some kind, the result being usually expressed in *foot-pounds* and given in a lump sum, as 10,000, meaning ten thousand foot-pounds : as in the case of the Integrating Dynamometer. But more frequently the result is a diagram area as by the Recording Dynamometer, which area, when measured by duly considering the co-ordinates and determining the area, represents the foot-pounds. Thus the steam engine *indicator* is, in one sense, a recording dynamometer, because the pressure ordinates of the indicator diagram multiplied by the stroke abscissas, gives an area which represents the foot-pounds of work performed by the engine for the corresponding stroke of that engine.

Sometimes the pressure or force ordinates only are indicated by the instrument, the space ordinates, or abscissas, being determined by some other means than by the so-called dynamometer. Thus the work done in drawing a plow along a furrow may be measured by observing at frequent equal intervals a spring dynamometer applied between the plow and whiffletree, while the distance, or space passed over by the plow at the same time, is measured by a tape line or similar means. Then, multiplying the mean tractile force, in pounds, given by the spring dynamometer, by the space in feet will give the foot-pounds of work which was required for turning the furrow by the plow and team, the entire work, friction and all, being measured. An ordinary spring balance for weighing may thus be used for a dynamometer, from which it would seem that this instrument is named according to the service required of it, as spring balance, dynamometer, etc. Dynamometers are divided into two classes, viz.: *Absorption Dynamometers* and *Transmission Dynamometers;* the former being especially adapted to the measurement of the power developed by motors, by absorbing or neutralizing it, usually by friction, but not applicable for measuring the power required to drive a lathe or grinding mill; while the second, or Transmission Dynamometer, is especially adapted for determining the amount of power necessary to drive a machine by measuring it while being transmitted to the machine. The Transmission Dynamometer may, however, be used also for ascertaining the power of motors, the instrument being applied near the motor and transmitting all its power.

According to Morin, the sensibility of a dynamometer should be proportional to the intensity of effects to be measured, and should not be liable to alterations by use. The indications of flexures should be obtained by methods independent of the attendance, fancies, or prepossessions of the observer, and should consequently be furnished by the instrument itself, by means of tracings, or material results, remaining after the experiments. The observer should be able to ascertain the effort exerted at each point of the path described by the point of application of the effort, or, in certain cases, at each instant in the period of observations. If the experiment from its nature must be continued a long time, the apparatus should be such as can easily determine the total quantity of work expended by the motor.

To meet these conditions various instruments have been designed by Morin, Webber, Briggs, Tatham, Brackett, Hartig, and others, all of which are sufficiently accurate for all practical purposes. But, in addition to possessing accuracy, and the other qualifications already mentioned, a dynamometer should be simple in construction, light for transportation, quick in adaptation, easy to read, and the results such as can be rapidly converted into the horse-power transmitted, and above all, the machine sufficiently cheap to be within reach of every manufacturer.

To this end, after a fruitless search in the market for a truly desirable instrument, the Transmission Dynamometer, illustrated in Fig. 1, was designed and built by the writer for the Testing Laboratory of the Ohio State University, where it has done admirable service. This machine consists essentially of a supporting frame, or pedestal, a T-shaped arm carrying the driving mechanism, and a graduated scale or weighing apparatus.

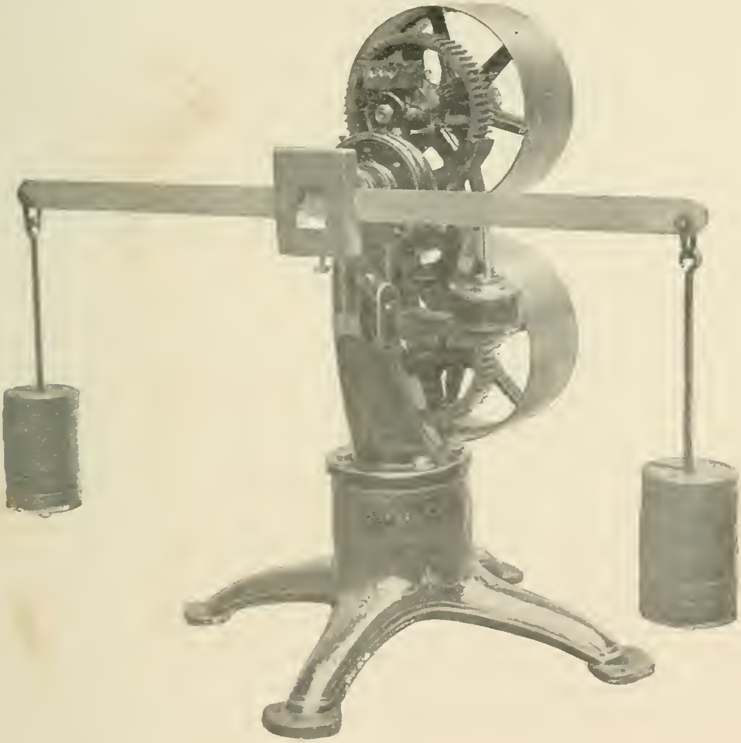


FIG. 1.

To use the instrument it is made fast to the floor with the pulleys under or to one side, but in the plane of the belt which drives the machine, the power to drive which is to be measured. Then with the machine set as shown in the illustration the lower pulley of the dynamometer is connected with the machine, while a second belt connects the pulley on the instrument with the pulley on the power shaft. This arrangement of pulleys enables the observer to connect his instrument without moving either the machine to be measured, or the driver on the main line.

The two pulleys of the instrument are mounted on a strong cross-tree bar so that they both overhang and can be swung around to any position. This overhang and swing makes it convenient to put either belt on or off without unlacing, and to swing the pulleys either way for tightening or loosening both belts. We may say, as a rule, both belts, for in setting the instrument up we can so set it, both as to location on the floor and position of cross-tree bearing, that by swinging the cross-tree one way we tighten *both*, or the other way loosen *both* belts. This movement of the cross-tree is made possible, and even convenient, by the cylinder and flange connection to the head of the column, the latter having screws and slots covering the full circle, so that the cross-tree may be set free to turn, and again made fast in any desired position. Thus the two pulleys may be swung about to any position in the whole circle to suit the particular location in hand. In swinging the pulleys and cross-tree thus, the set screw, making fast the poise bar, should be slackened and again tightened when the desired position is found. Thus the driving belt may come down from above, from the one side, or from below to its proper pulley on the short arm of the cross-tree; while the pulley on the longer arm is to be connected to the machine to be measured, the cross-tree being first set, if desired, so that both belts are loosened or tightened simultaneously, due regard being paid to the poise-bar set screw.

Sometimes it may be desired to slacken up for conveniently laying off the belts, as well as to tighten them. This feature of perfect adaptation for tightening or loosening the belts has been found a most useful one in practice with this dynamometer, as the belts can always be given the necessary tightness without going beyond the most suitable conditions.

The pulleys have each a gear on the end of the hub, both of which mesh into a smaller gear between, the latter being supported on a pin made fast as a crank pin in the arm from a shaft which passes through the centre of the hub of the cross-tree in the head of the main column. To the opposite end of this shaft the poise bar is made fast by a set screw in a boss to which the poise bar is secured. Thus when the small intermediate gear is thrust to the one side or the other by the large gears, the poise bar is correspondingly moved.

It will now be readily understood that as work is transmitted from one pulley to the other through the intermediate gear on the crank pin, the latter will be thrust to one side with a force proportioned to the effort transmitted, and that the same will tend to tip the poise bar, to prevent which weights are applied. It is plain that the equilibrating weights on the poise bar of a duly calibrated instrument together with speed, etc., furnish data for calculation of the work being transmitted.

The poise bar is graduated and has a sliding weight, called poise weight, to move from one end to the other, and the graduations count from 0 at the middle to 10 at either end. At each end of the bar is a knife-edge pin to which is suspended a rod and foot plate, or pan, that may carry fourteen or less weights of five lbs. each. Every weight is marked "5 lbs.=100 ft. lbs. per rev. as shifted from pan to pan."

In starting an experiment, the fourteen weights, or less if preferred, may be equally divided between the opposite ends of the poise bar, and the poise weight may be in the middle of the poise bar, when the latter is in equilibrium, or balanced. Now the poise weight is moved out more and more on the poise bar till the end is reached if not sooner equipoised by the work being transmitted. Then the poise weight is brought back to the centre, and one 5-lb. weight at the same time moved over from one poise pan to the other, the same making a difference of 10 lbs. and just equal to the 10 of the poise weight moved from end to centre. Then the poise weight is moved out more and more again till the end figure 10 is again reached, if not sooner equilibriated, when it is again moved back and another 5-lb. weight moved over, and so on. Finally an equilibrium is found as between the poise bar at one end and the gears at the other end of the crank shaft. Then a count of the weight will tell the number of pounds that acted to turn the poise bar; the poise weight being perhaps at 6, and the 5-lb. weights perhaps adding up to 30, as if 3 weights were moved over from one side to the other. It is to be observed that each 5-lb. weight moved over counts 10 in the equipoise, as by taking 5 off of one side and putting it on the other making 10 in effect.

The three weights moved over then count 30 pounds and the poise weight counts 6 pounds, making 36 pounds in all. The work being transmitted is therefore 360 foot-pounds per revolution, the number of pounds being multiplied by ten to give the foot-pounds per revolution.

Another way to count is to keep track of the number of weights moved over, each counting 100 foot-pounds. Then the three weights and the six on the poise bar make in effect 3.6 weights or 360 foot-pounds per revolution.

The tables are added to illustrate the calibration and the reduction of observations made with the instrument.

TABLE I.

Giving corrections for readings taken from the Transmission Dynamometer in use at the Ohio State University.

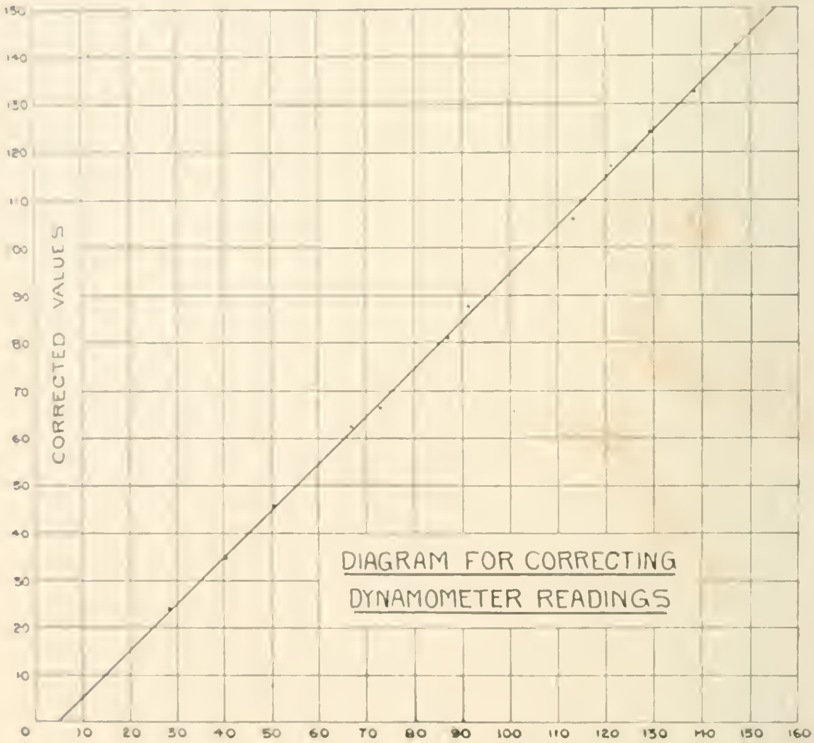


Table I shows that readings from the instrument mentioned are very readily corrected, it simply requiring five to be deducted.

The diagram also shows that the various results of observation plot very near to a straight line lying at an angle of 45°, there being a close agreement between the various observations. Each new instrument should have a correcting diagram of some kind made out for itself, as the law of each instrument may differ from that of another.

Table II is an example of results of observations for determining the horse-power required to drive a ventilating fan of about 5 feet diameter.

TABLE II.

POWER REQUIRED TO DRIVE A VENTILATING FAN.

SIZE OF FAN ORIFICE.	DYNAMOMETER READINGS.	CORRECTED DYN. READINGS, FT. LBS. PER REV.	REVOLUTIONS PER MINUTE.	H. P. TO RUN FAN.
1 foot	310.0	305.0	336	3.11
2 feet	285.3	280.3	432	3.70
3 feet	259.3	254.3	444	3.40
4 feet	127.6	122.6	328	1.22
4 feet	214.5	209.5	450	2.86
4 feet	224.5	319.5	440	2.93
4 feet	256.0	251.0	460	3.50
4 feet	254.1	248.1	490	3.68

The figures in the column of readings are the means of several readings, and hence the decimals.

The corrected readings are obtained from the Table I above for correcting the readings of this instrument which gave these results. The Table I shows that 5 is to be subtracted, simply from each reading, thus explaining the difference between columns 2 and 3. Hence in column 3 we have the foot-pounds per revolution of dynamometer pulley. Before correcting, we have, as readings, the figure 310, which means that three of the 5-pound weights had been passed over from one scale pan to the other, making 300 foot-pounds per revolution while the poise bar read 1 or 10 foot-pounds per revolution, making 310 foot-pounds per revolution as uncorrected.

But other instruments may not always give readings, the correction for which will be 5 to subtract, but some figure to be determined by calibration, similarly as was done for Table I.

Among the advantages of this instrument may be mentioned its adaptation for receiving the belts from any direction as down from above, from one side, or up from below. In each case, the most advisable arrangement is to place the cross-tree, on which the pulleys are mounted, in such position that both belts will be tightened by swinging it in one direction, or loosened by swinging in the opposite direction, the belt to take the power force to the machine to be measured being that from the pulley on the longer arm of the cross-tree. Then the belts can be adjusted any time to be just at the desired tightness without relacing, and by simply swinging the cross-tree arm.

Formulas for the Dynamometer will be found useful in practice. To this end take

D = diameter of the belt pulley (driven pulley).
R = radius of gear on that pulley.
r = radius of the intermediate gear, and radius of crank arm.
l = half length of poise bar.
W = difference of weights on scale pans.
w = poise weight, "reduced" to scale pan.
F = difference of belt tensions on driven pulley.
T = tangential component of pressure between gear teeth.
f = pressure against crank pin.
n = number of revolutions of pulley per minute.
S = square ft. of belt per H. P. per minute.
u = width of belt on dynamometer pulley.

Then

$$f = 2T = 2F\frac{D}{2R} = \frac{FD}{R}$$

$$fr = (W + w)l = \frac{FDr}{R}$$

$$\frac{\pi D n u}{S} = H.P. = \frac{F\pi D n}{33000}$$

or

$$\frac{F}{33000} = \frac{u}{S}$$

and

$$(W + w)l = \frac{Dr}{R} \cdot \frac{u}{S} \cdot 33000$$

In the 25 H. P. instrument at the Ohio State University Mechanical Testing Laboratory, $D = 14$ inches, $R = 5$ inches, $r = 3\frac{1}{12}$ inches, $l = 23.54$ inches, and $u = 6$ inches.

Then, taking the highest value of n at 1,000, and solving for S, we have

$$S = \frac{\pi D n u}{H.P.} = \frac{3.\text{[illegible]}\ 1000\ \text{[illegible]}}{25} = 73.3$$

giving 73.3 square feet of belt per minute passing over the pulley when the instrument is working to its highest capacity. This figure is more ample than the 60 determined by J. H. Cooper as a fair value some years ago.

The quantity of weights to accompany the instrument is

$$W + w = \frac{Dr}{l\,R}\,\frac{u}{S}\,33000 = 82 \text{ lbs.}$$

as found by substituting and reducing.

Making the weights of 5 lbs. each and allowing 10 lbs. for the equivalent of the poise weight, we find we require a trifle over 14 weights, but propose 14 as the number to go with the instrument.

In this case 7 or less may be placed on each pan in starting an experiment, the poise weight being at the centre. This collection of weights on poise bar will serve as an efficient inertia damper to check jerky movements of the poise bar, and reduce demands upon the dash-pot.

Then, as above explained, proceed by moving the poise weight slowly out to the end of the graduation, 10, if not sooner balanced by the power transmitted. Then move the poise weight back to 0, and move over a 5-lb. weight from one pan to the other which amounts to 10 in effect, and equals the effect of the poise weight just returned to centre; then move the poise weight out again to 10 if not sooner balanced; then moving it back to 0 and transfer another 5-lb. weight from pan to pan, and so proceed till the balance is obtained between power and poise bar. Then count up the weights moved over, each being counted for 100 foot-pounds per revolution, allowing the same for the poise weight clear out, as already described in the previous example. If 4 weights were moved over, they would count 400 foot-pounds per revolution, and if the poise weight were clear out it would count 100, or 500 foot-pounds per revolution in all. Or if the poise weight were at 3.7 the count would be 437 foot-pounds per revolution, etc. If running at 100 revolutions per minute the H. P. transmitted would be

$$\frac{43700}{33000} = 1.324 \text{ H. P.}$$

PAVING BRICKS.

TESTED FOR COMPRESSIVE STRENGTH AND ABSORPTION (PER CENT.).

By J. Paul Anderson, M. E., Professor of Mechanical Engineering,
State College of Kentucky, Lexington, Ky.

THE following tables present the results of a series of tests on twenty different kinds of paving bricks to determine their compressive strengths and the per cent. of moisture absorbed.

A brick to be well adapted for street paving purposes must, first of all, have a good compressive strength.

Secondly, a paving brick must not be brittle, therefore its spalling point should be high.

Thirdly, a paving brick should not absorb more than 3.5 per cent. of moisture.

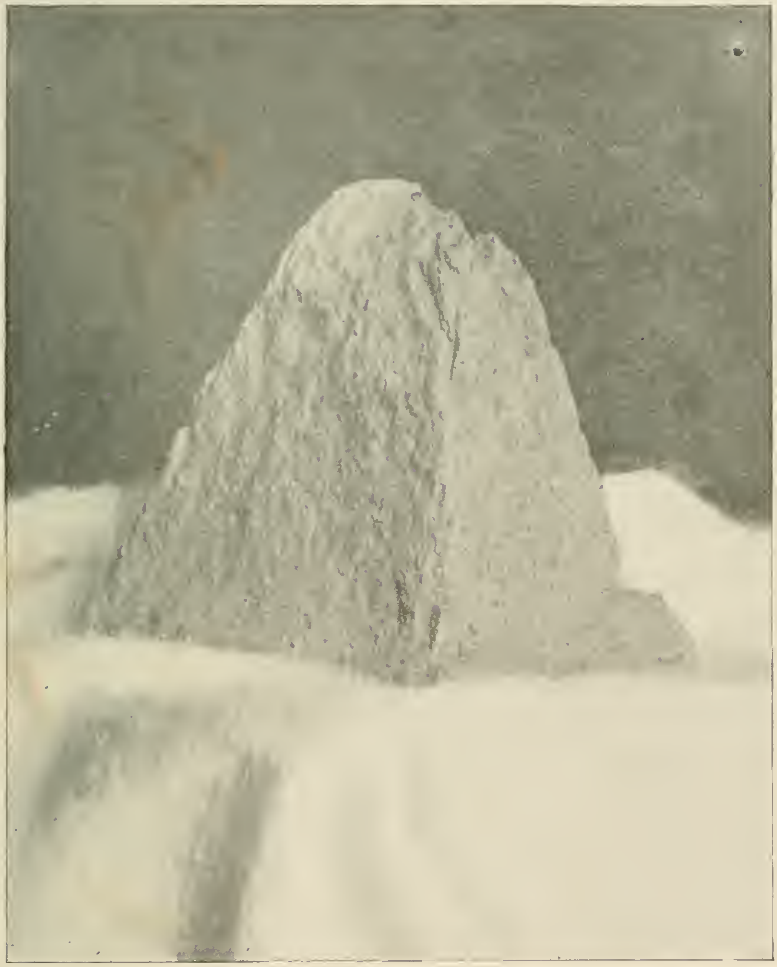
The last qualification is regarded, by some street-paving engineers, to be most important, for they contend that all bricks are practically strong enough to carry all loads put upon them, and that the tendency to disintegrate determines the life of a brick. The continued freezing and thawing of a brick full of water surely starts internal fractures.

The compressive tests of the bricks hereafter recorded were conducted with great care. The bricks were first cut in half by a skillful stone cutter; their middle faces were ground parallel. A Riehlé 100,000 pound Screw Testing Machine was used in the work, and for several specimens the machine was loaded 25 per cent. above its capacity. The specimens were imbedded in plaster of Paris on the compression plates, the line of stress being coincident with the line of pressure in practice. (The bricks were crushed on edge.)

After each test, the machine was balanced to avoid any error.

The ordinary plan employed in the testing of bricks for absorption was not adopted in this case. The usual method is to cut the brick in half and put both halves in water for seventy-two hours, weighings being made before and after immersion.

This method I deem unscientific and unfair, as glazed and unglazed bricks surely would not be tested on the same basis.



FRACTURE OF A MACK FIRE CLAY BRICK.

The plan employed in the tests recorded was to cut from the interior of the bricks, avoiding all glazed surface, a block which was solid and free from cracks.

These blocks were dried and weighed on a chemical balance to within 1-500 of a grain, then immersed in water twenty-four hours and weighed again, giving the per cent. of moisture absorbed very accurately.

I also present photographs of fractures of sets of bricks, which indicate very clearly the homogeneous structure, comparatively, of the various types. On page 109 is shown a fracture of a Mack fire-clay brick, which approaches very nearly the pyramidal form.

On page 111 is shown the two pyramidal fractures of a Mack fire-clay block just as they stood in the machine after the final giving way of the specimen.

In some cases the number of specimens tested of each set, was not large, but included all we were able to secure.

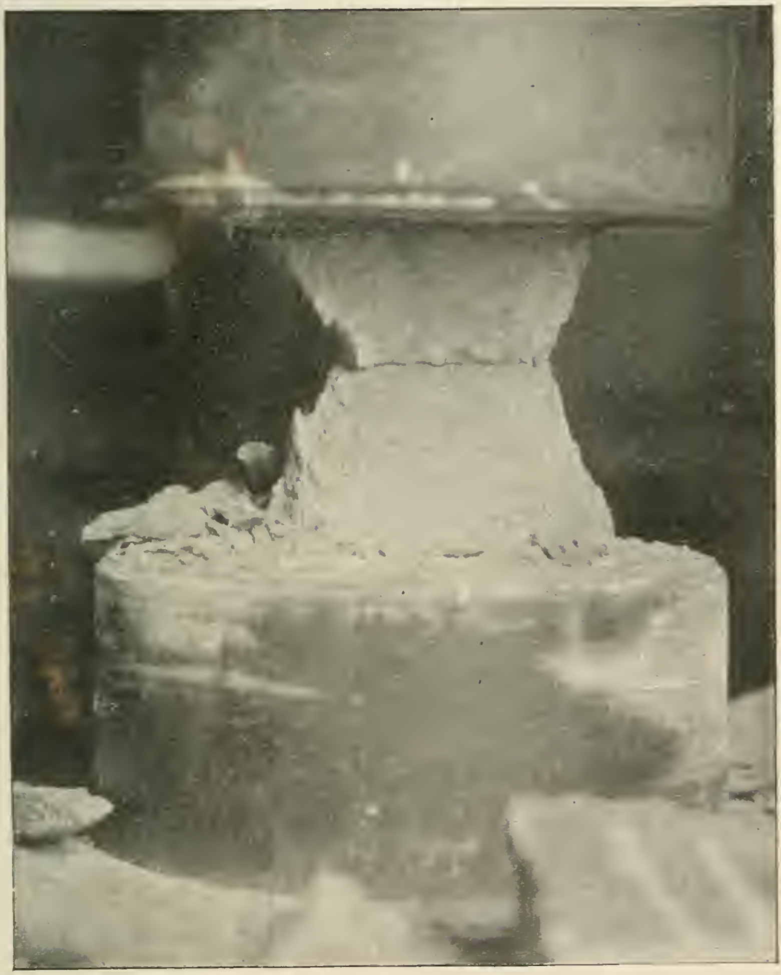
Most of the varieties in question contained over six specimens, therefore the average results are to be depended upon.

For a number of years some of the makers of paving bricks have contended that a paving brick should not absorb more than 2.5 per cent. of moisture, and in most of the cities specifications for street paving have specified that any brick absorbing more than 2.5 per cent of moisture would be rejected.

Experience has proven that a first-class paving brick may absorb as much as 4 per cent. of moisture, and it has been unfortunate that makers of paving bricks, in order to comply with the 2.5 per cent. requirement, have gone to the other extreme, and are putting upon the market a brick almost impervious to water, but one extremely brittle and glassy.

When a paving brick becomes impervious to water we are bound to make the same so rigid and brittle that its pliability is lost, and therefore loses one of the most desirable features of a successful paving brick.

The record of tests for compressional strength and the amount of moisture absorbed, herewith presented, includes twelve of the most important and reliable paving bricks made in the country, and the illustrations of the fractures form an important feature, for by these fractures we are able to determine, to a large extent, the homogeneity of the paver, and by this means the care with which the material is ground and worked will be apparent.



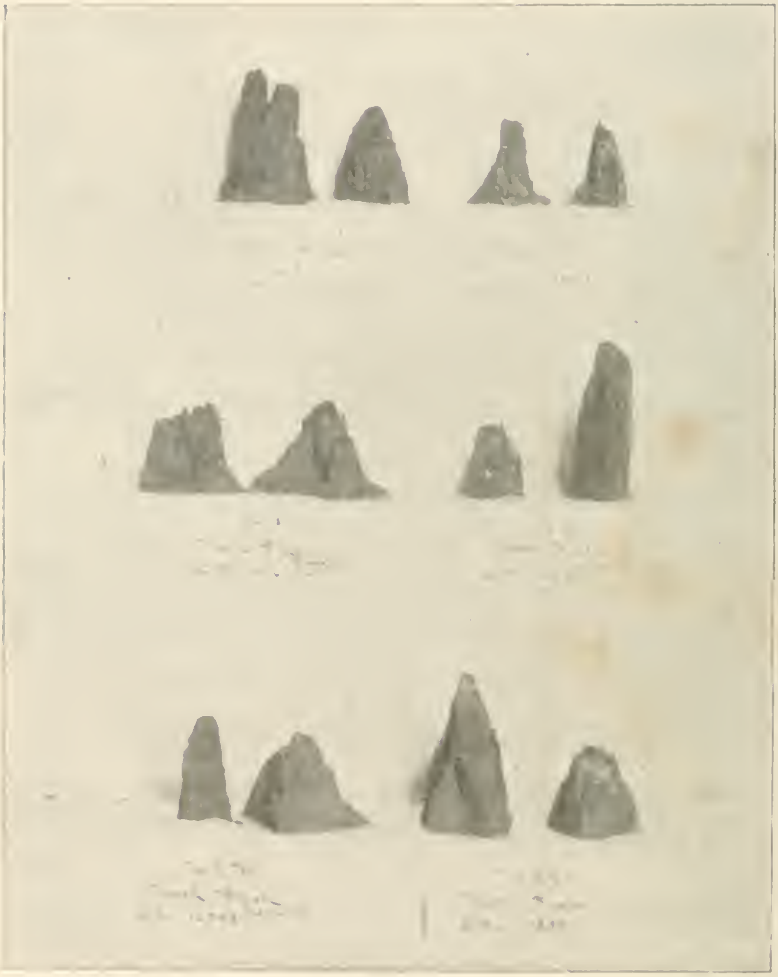
Pyramidal Fractures of a Mack Fire Clay Block.

REPORT OF ABSORPTION TESTS OF

Company Submitting Specimen.	Locality.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Color.
Charles Spinks & Son,	Portsmouth, Ohio,	Glazed,	9 x4 x3	Bluish brown,
P. Bannon, ...	Louisville, Ky., . .	Ungl'zd,	8½x4 x2½	Brownish red,
Grant R. B. Co., . .	Middleport, Ohio, .	Glazed,	9 x4 x3	Dark brown,
Lyttle & Dolan, . .	Philipsburg, Pa., .	Ungl'zd,	8½x4 x2½	Dark red, . .
Grant R. B. Co., . . .	Middleport, Ohio, .	Glazed,	8 x4 x2½	Bluish brown,
Charles Spinks & Son,	" " .	"	9 x4 x3	Dark brown,
Lyttle & Dolan, . .	Ironton, Ohio, .	"	9 x4 x2½	"
" " . . .	Canton, Ohio, . .	Ungl'zd,	8½x4 x2½	Brownish red,
Hunt'ton Construct. Co.,	New Cumb'ld, W.Va.	"	9 x4 x3	"
Charles Spinks & Son,	Portsmouth, Ohio,	Glazed,	9 x4 x3	Red'sh brown,
Hunt'ton Construct. Co.,	New Cumb'ld, W.Va.	Ungl'zd,	8 x4 x2½	Dark red, . .
" "	" "	"	8 x4 x2½	"
" "	" "	"	8 x4 x2½	Yel'ish brown,
Standard Construct. Co.,	Robbins, Tenn.,	"	8 x4 x2½	"
Hunt'ton Construct. Co.	New Cumb'ld W.Va.	"	8½x4 x2½	"
Standard Construct. Co.	Robbins, Tenn., .	Glazed,	9 x4 x2½	Dark brown,
Hunt'ton Construct. Co.,	New Cumb'ld, W.Va	Ungl'zd,	9¼x4 x3	Yel'ish brown,
Standard Construct. Co.,	Robbins, Tenn., .	"	9 x3¾x2½	"
" "	" " .	Glazed,	8½x4¼x2½	Dark brown,
Lexington Brick Co.,	Lexington, Ky., .	Ungl'zd,	8½x4 x2½	Dark red, . .

TWENTY KINDS OF PAVING BRICKS.

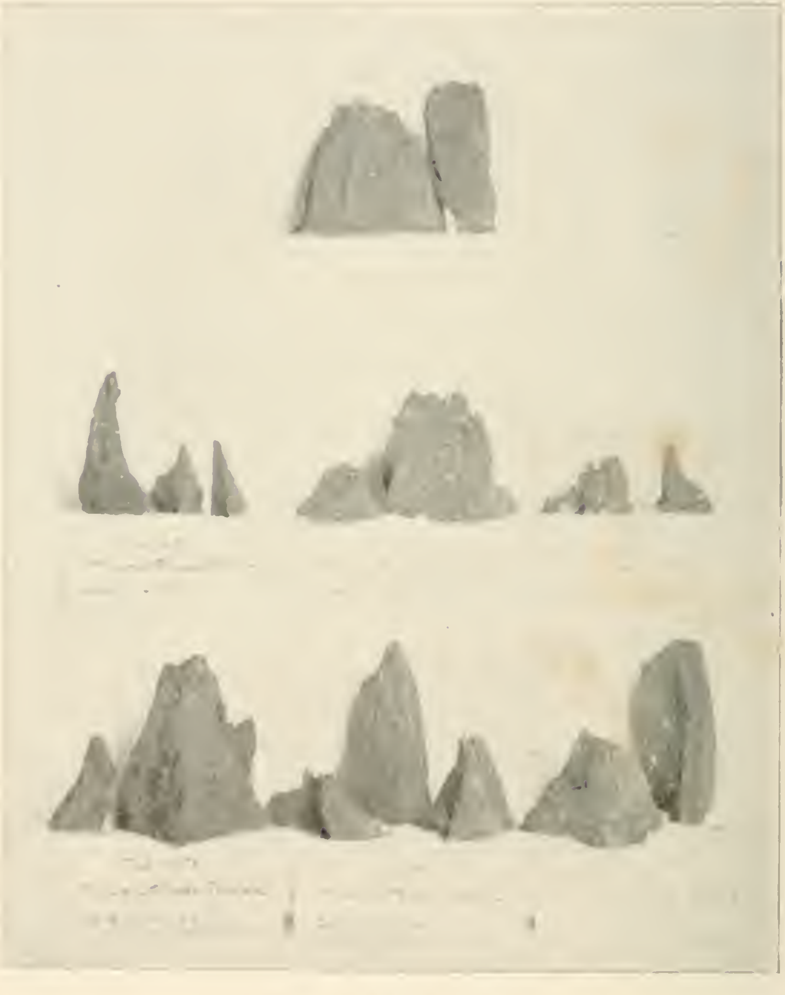
Label attached to Specimen.	Weight of Specimen in Grams when Dry.	Weight of Specimen in Grams after being Submerged in Water.	Gain in Weight in Grams.	Per Cent. of Gain in Weight.	Remarks.
Kentucky Block, . .	425.19	427.55	2.36	.55	Middle edges sharp. Two continuous grooves on largest and smallest faces.
Bannon Brick, . . .	211.42	213.14	1.72	.81	Smallest edges round.
McManigal, ...	287.81	291.85	4.04	1.4	
Monongahela Shale, .	262.79	266.84	4.05	1.54	Edges sharp.
Riverside Paver, . .	317.23	322.37	5.14	1 62	Three grooves on back.
Grant Block R. B. Co.,	312.85	318.02	5.17	1.65	Middle edges sharp. Three grooves on back.
Ironton F. B. C. Paver,	253.37	257.61	4.24	1.67	Edges sharp.
Canton Shale Paver,	343.01	349.97	6.96	2.02	Edges sharp.
Mack Shale Block, .	232.81	237.77	4.96	2.13	Middle edges sharp.
Charles Spinks & Son,	377.16	385.30	8.14	2.16	Two grooves on largest faces.
Mack Shale Re-pressed Brick, .	232.81	238.84	6.03	2.58	Middle edges sharp.
Mack Shale Standard A Square, .	455.12	468.06	12.94	2.84	Edges sharp.
Mack Fire Clay Re-pressed Brick,	236.09	242.85	6.76	2.86	Middle edges sharp.
Robbins Paver, . . .	187.27	193.25	5.98	3.19	Middle edges sharp.
Mack Fire Clay Standard A Square,	245.12	253.06	7.94	3.24	Shortest edges round.
Hallwood Block, . .	190.17	196.35	6.18	2.25	Middle edges sharp. Two continuous grooves on largest and smallest faces.
Mack Fire Clay Block,	366.73	379.25	12.52	3.41	
Hallwood Block, . .	176.61	183.46	6.85	3.87	Middle edges sharp. Two continuous grooves on longest and smallest faces.
Robbins Paver, . . .	240.85	251.13	10.28	4.27	Middle edges sharp.
Lexington Brick, . .	244.21	282 43	38 22	15.65	Edges sharp.



FRACTURES OF SETS OF FIRE BRICKS.

REPORT OF COMPRESSION TEST OF TWENTY KINDS OF PAVING BRICKS.

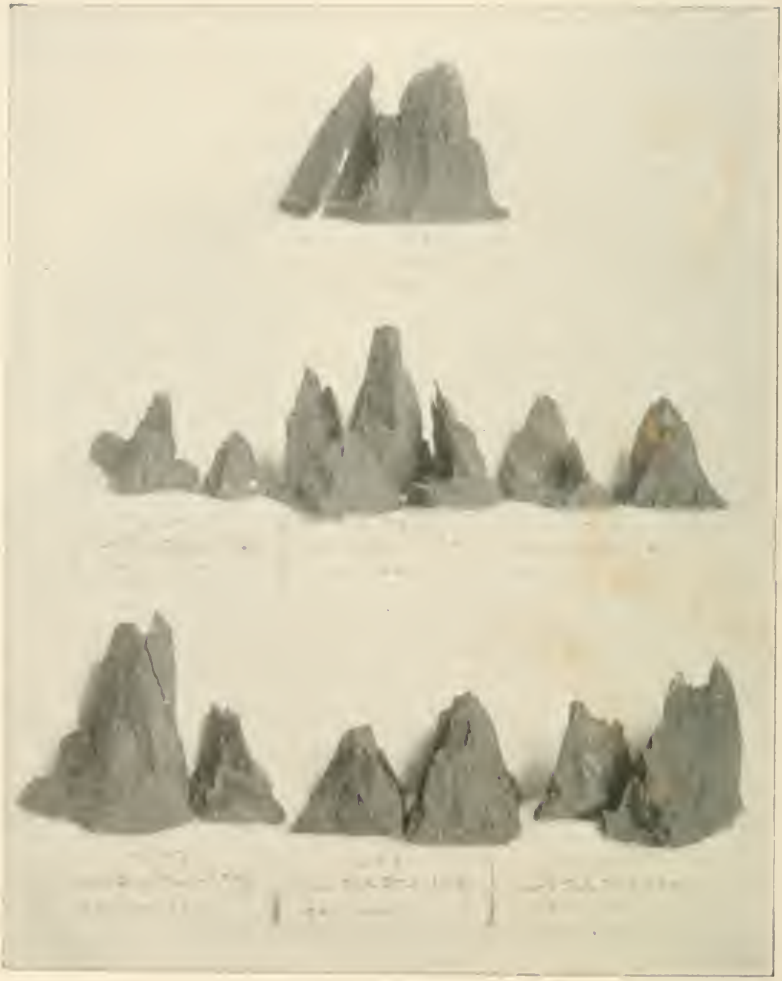
Company Submitting Specimen.	Locality.	Number of Specimens from which Average was Obtained	Character of Surface of whole Brick.	Approximate Size of whole of Brick in Inches.	Color.	Label attached to Specimen.	Load at which Specimen Began to Spall.—Pounds.	Crushing Strength per Square Inch.—Pounds.
Lyttle & Dolan, ...	Canton, Ohio, ...	2	Unglazed	8½x4 x2½	Dark red, . . .	Standard Canton Shale Paver, . . .	60,365	14,253
Huntington Construction Co.,	New Cumberland, W. Va.,	7	"	8 x4 x2½	" . . .	Mack Shale Re-pressed Brick, . . .	56,111	12,276
Lyttle & Dolan, ...	Philipsburg, Pa., ...	1	"	8½x4 x2½	" . . .	Monongahela Shale Paver, ...	66,600	10,342
Huntington Construction Co.,	New Cumberland, W. Va.,	9	"	8½x4 x2½	Yellowish brown,	Mack Fire Clay Standard A Square,	50,053	10,709
" "	" "	7	"	9 x4 x3	Dark red, . . .	Mack Shale Block, ...	28,990	9,870
" "	" "	7	"	8 x4 x2½	" . . .	Mack Shale Standard A Square, . .	35.775	8,997
Charles Spinks & Son, ...	Portsmouth, Ohio, . . .	6	Glazed,	9 x4 x3	Reddish brown,	Kentucky Block, ...	22,105	7,785
Huntington Construction Co.,	New Cumberland, W. Va.,	9	Unglazed,	8½x4 x2½	Yellowish brown,	Mack Fire Clay Re-pressed Brick, .	37.972	7.354
Charles Spinks & Son, ...	Portsmouth, Ohio, . . .	9	Glazed,	9 x4 x3	Reddish brown,	Charles Spinks & Son, ...	30,847	7,161
Lyttle & Dolan, ...	Ironton, Ohio, ...	7	Unglazed	9 x4½x2½	Dark brown, . .	. . . .	18,617	6,663
Huntington Construction Co.,	New Cumberland W. Va.	9	"	9 x4 x3	Yellowish brown,	Mack Fire Clay Block, ...	47,209	6,589
P. Bannon, ...	Louisville, Ky., ...	3	"	8½x4 x2½	Brownish red, .	Bannon Brick, ...	17,610	6,044
Standard Construction Co., .	Robbins, Tenn , ...	7	"	8½x4 x2½	Yellowish brown,	Robbins Paver, ...	26,030	5,815
" " .	" "	9	Glazed,	8½x4 x2½	Dark brown, . .	" "	20,421	4,784
" " .	" "	9	Unglazed.	9 x4 x2½	Yellowish brown.	Hallwood Block, ...	21,668	4,765
" " .	" "	9	Glazed,	9 x4 x2½	Bluish brown, .	" "	20,867	3,979
Lexington Brick Co., ...	Lexington, Ky , ...	9	Unglazed	8½x4 x2½	Dark red, . . .	Lexington Brick, ...	24,283	3,694
Grant R. B. Co., ...	Middleport, Ohio, ...	2	Glazed,	8 x4 x2½	Bluish brown, .	Grant R. B. Co., ...	12,165	3,398
Charles Spinks & Son, ...	" "	9	"	9 x4 x3	Dark brown, . .	Charles Spinks & Son, ...	14,932	3,265
Grant R. B. Co., ...	" "	2	"	9 x4 x3	" . .	McManigal, ...	10,038	2,747



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

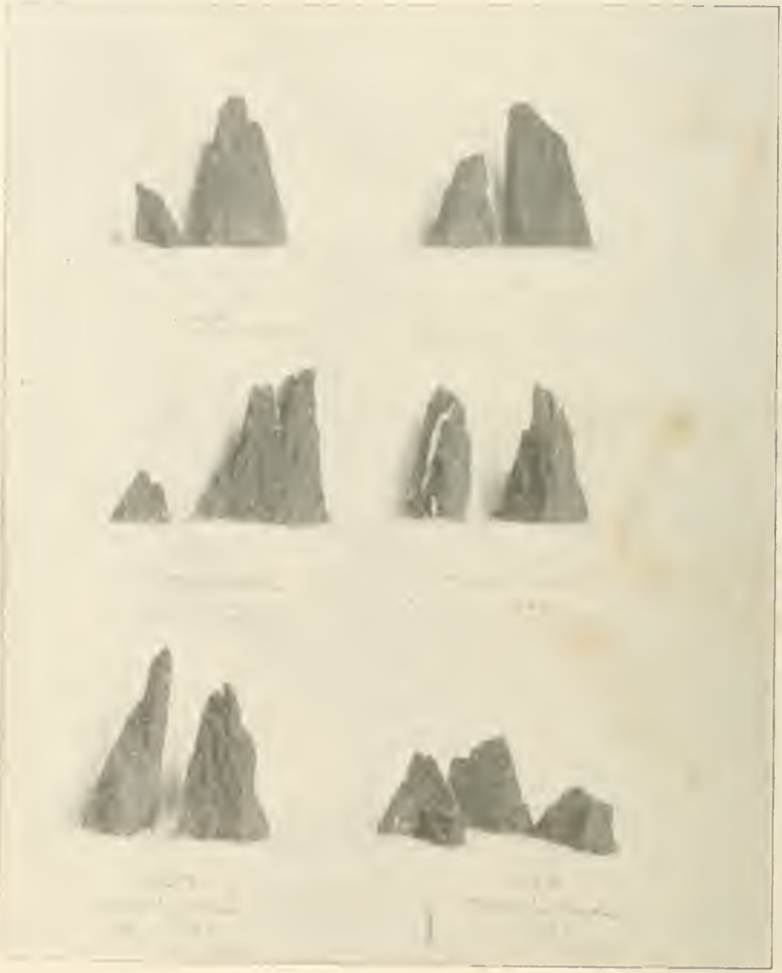
MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Standard Canton Shale Paver. Made from shale obtained at Canton, Ohio. Samples dark red. Furnished by Lyttle & Dolan, ...	2 AF	Unglazed,	8½x4x2½	2.53	2.83	7.15	3.73	38,140	85,115	11,904	
	1 AS	"	"	2.50	2.39	5.98	4.12	82,590	99,280	16,602	
								60,365	Average,	14,253	
Mack Shale, Re-pressed Brick. Made from shale obtained at New Cumberland, W. Va. Samples dark red. Furnished by Huntingdon Construction Co., ...	1 A	Unglazed,	8x4x2½	2.35	3.17	7.45	4.13	62,920	118,170	15,862	
	1 B	"	"	2.37	2.80	6.64	4.15	27,010	93,710	14,113	Light
	2 B	"	"	2.35	2.60	6.11	4.14	50,590	75,510	12,358	Heavy.
	6 A	"	"	2.30	2.70	6.21	4.20	25,850	66,230	10,665	Light.
	6 B	"	"	2.37	2.69	6.38	4.23	44,480	76,760	12,031	Very light.
	5 A	"	"	2.39	2.96	7.07	4.24	21,000	76,710	10,850	Light.
	7 B	"	"	2.43	2.64	6.42	4.24	21,080	64,560	10,050	
								36,133	Average,	12,276	
Monongahela Fire Clay Co.'s sample shale paver. Made from shale obtained at Philipsburg, Pa. Samples dark red. Furnished by Lyttle & Dolan, ...	2 AF	Unglazed,	8½x4x2½	2.45	2.63	6.44	3.82	19,550	66,600	10,342	Light.



Fractures of Sets of Fire Bricks.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

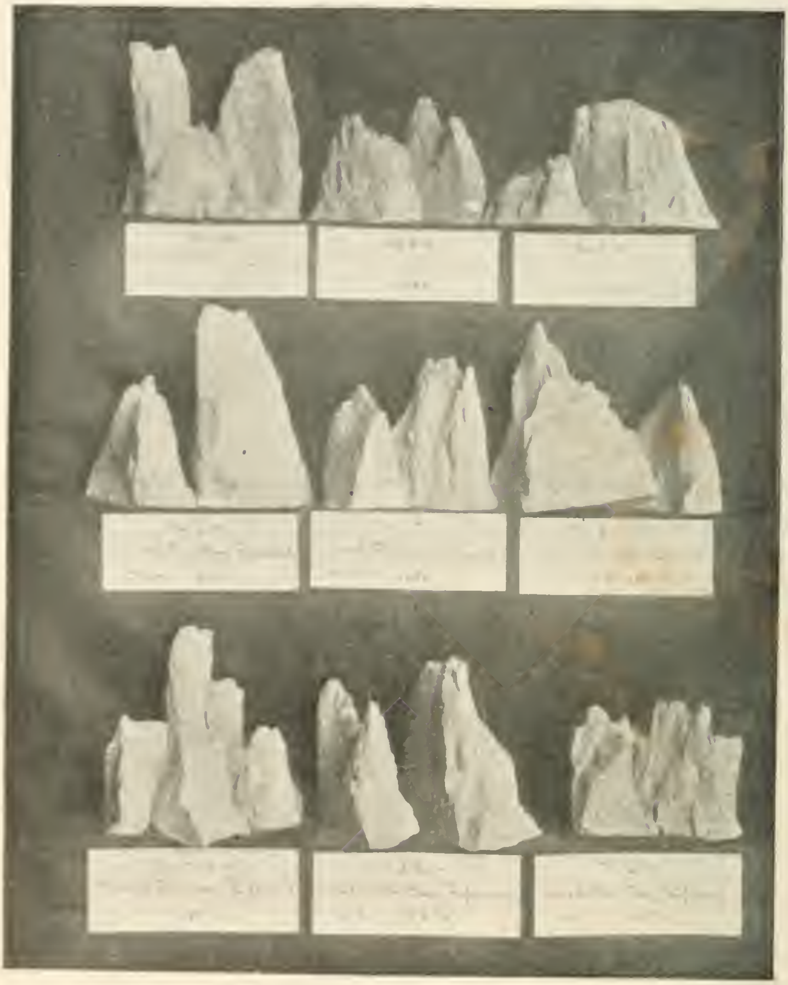
MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Robbins Paver. Made from fire clay obtained at Robbins, Tenn. Samples yellowish-brown. Furnished by Standard Construction Co, ...	6 A	Unglazed,	8½x4x2½	2.48	4.25	10.54	4.21	27,010	52,270	4,959	Light.
	5 A	"	"	2.60	4.42	11.49	4.38	18,760	30,320	2,639	
	1 B	"	"	2.60	4.37	11.36	4.19	18,000	66,810	5,881	
	5 B	"	"	2.57	4.29	11.02	4.37	24,910	50,355	4,569	
	6 B	"	"	2.51	4.14	10.39	4.19	31,970	93.580	9,007	Light.
	2 A	"	"	2.43	4.10	9.96	4.18	41,130	65,260	6,553	
	2 B	"	"	2.46	4.32	10.62	4.23	20,430	75,420	7,101	
								26,030	Average.	5,815	
Hallwood Block (Unglazed Paving Brick). Made from fire clay obtained at Robbins, Tenn. Samples yellow-brown. Furnished by Standard Construction Co., ...	1 B	Unglazed,	9x4x2½	2.48	4.66	11.55	3.67	7,100	50,955	4,412	
	2 B	"	"	2.50	4.66	11.65	3.71	23,760	61,690	5,295	Heavy.
	2 A	"	"	2.50	4.48	11.20	3.72	25,270	74,690	6,668	"
	5 A	"	"	2.53	4.61	11.66	3.78	9,750	58,480	5,015	
	5 B	"	"	2.54	4.50	11.43	3.81	23,640	37,800	3,307	Heavy.
	6 A	"	"	2.49	4.61	11.50	3.82	22,910	55,660	4,840	"
	6 B	"	"	2.46	4.23	10.40	3.82	20,540	28,630	2,752	"
	7 A	"	"	2.51	4.50	11.29	3.68	28,070	48,410	4,288	"
	7 B	"	"	2.52	4.63	11.66	3.64	33,970	73,590	6,311	
								21,668	Average.	4,765	



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

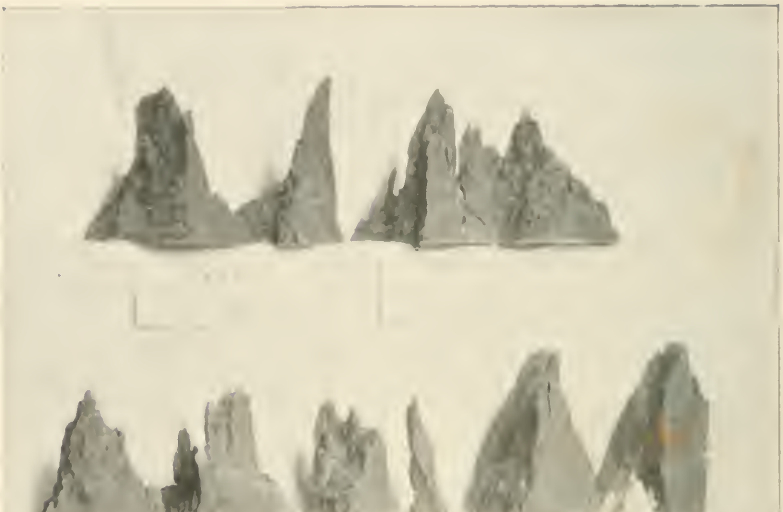
MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Mack Fire Clay Standard A Square Paving Brick. Made from fire clay obtained at New Cumberland, W. Va Samples yellowish brown. Furnished by Huntington Construction Co., . .	1 B	Unglazed,	8½x4x2½	2.57	3.29	8.45	4.02	65,500	80,900	9.574	
	2 A	"	"	2.55	4.09	10.43	4.00	116,610	120,310	11,535	
	2 B	"	"	2.56	3.42	8.75	4 05	43,600	71,390	8,159	Light.
	5 A	"	"	2.55	3.38	8 62	4.13	61,370	99,710	11.567	
	5 B	"	"	2.54	3.26	8.28	4.12	26,740	95,960	11,590	Light.
	6 A	"	"	2.59	3.26	8.44	4.14	43,990	71,360	8,455	Very light.
	6 B	"	"	2.64	3.33	8.79	4.13	37,620	80,670	9,177	Very light.
	7 A	"	"	2.55	2.65	6.75	4.16	10,000	71,005	10,520	Light.
	8 B	"	"	2.56	3 18	8.14	4.06	45,050	92,020	11,304	Light.
								50,053	Average.	10,209	
Mack Shale Paving Block. Made from shale obtained at New Cumberland, W. Va. Samples dark red. Furnished by Huntington Construction Co., ...	1 A	Unglazed,	9x4x3	3.07	3.21	9.85	3.92	32,450	85.470	8,677	Light.
	1 B	"	"	3.00	3.25	9.75	3.87	44,910	87,910	9,016	Heavy.
	2 A	"	"	3 01	3.17	9 54	3 82	25,280	64,200	6.730	Light.
	2 B	"	"	2.98	2 94	8.76	3 94	47,980	112,210	12 809	Heavy.
	5 B	"	"	3.22	3.00	9.66	3.97	19,270	83,820	8.677	
	5 A	"	"	3.18	2.97	9.44	3.99	12,600	95,200	10,085	
	6 B	"	"	3 10	2.80	8.68	3.96	20,440	113,720	13,101	
								28,990	Average,	9.870	



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square inch.—Pounds.	Spall.
Mack Shale Standard A Square Paving Brick. Made from shale obtained at New Cumberland, W. Va. Samples dark red. Furnished by Huntington Construction Co., ...	1 B	Unglazed,	8x4x2½	2.47	4.22	10.42	4.00	44,200	120,880	11,601	Lt. on cors.
	5 A	"	"	2.57	4.25	10.92	4.23	17,530	68,830	6,303	Very light.
	5 B	"	"	2.56	4.30	11.00	4.13	34,000	93,010	8,455	" "
	6 A	"	"	2.47	3 91	9 66	4.16	57,480	109,260	11,311	" "
	6 B	"	"	2.47	4.08	10.07	4.13	17,910	99,610	9,891	" "
	7 A	"	"	2.54	4.18	10.62	4.15	30,000	70,200	6,610	" "
	7 B	"	"	2.54	4.08	10.36	4.17	49,310	91,270	8,810	" "
								35 775	Average,	8,997	
Mack Fire Clay, Re-pressed Paving Block. Made from fire clay obtained at New Cumberland, W. Va. Samples yellowish brown. Furnished by Huntington Construction Co., ...	1 B	Unglazed,	8½x4x2½	2.48	4.26	10.56	4.31	20,730	58,700	5,558	
	2 A	"	"	2.47	4.21	10.39	4.26	67,200	92,250	8,878	Light.
	2 B	"	"	2.45	4.21	10.31	4.27	79,590	89,490	8,680	Very light.
	5 A	"		2.46	4.19	10.3	4.38	31,530	69,150	6,714	Heavy.
	5 B	"	"	2.47	4.30	10.62	4.41	13,230	80,710	7,600	Light.
	6 A	"	"	2.44	4.28	10 44	4.42	28,560	58,290	5.583	Heavy.
	6 B	"	"	2.47	4.28	10.57	4.39	27,560	85,300	8,070	Light.
	7 A	"	"	2.46	4.2	10.33	4.4	61,350	94,320	9,130	"
	7 B	"	"	2.47	4.32	10.67	4.35	12,000	63,740	5,974	"
								37,972	Average,	7,354	



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
McManigal Paving Block. Made from plastic clay obtained at Middleport, Ohio. Samples dark brown. Furnished by Grant R. B. Co., ...	1 AF	Glazed,	9x4x3	3.10	2.96	9.17	3.91	13,856	28.500	3,114	Heavy.
	2 AS	"	"	3.08	2.32	7.14	3.90	6,220	17,000	2,380	Light.
								10,038	Average.	2,747	
Star Block Paving Brick. Made from a mixture of shale and fire clay obtained at Portsmouth, Ohio. Samples red brown. Furnished by Charles Spinks & Sons, ...	5 B	Glazed,	9x4x3	3.09	4.48	13.84	4.12	15.500	85,130	6,151	
	6 A	"	"	3.09	4.60	14.21	4.12	29,170	118,990	8,373	
	8 A	"	"	3.06	4.55	13.92	4.13	47,000	99,350	7,138	
	6 B	"	"	3.10	4.57	14.16	4.14	53,780	116,510	8,228	
	7 B	"	"	3.09	4.52	13.96	4.08	24,860	130,000*	9,312	
	5 A	"	"	3.09	4.57	14.12	4.13	42,000	101,400	7,181	
	2 A	"	"	3.12	3.02	9.42	4.09	13,190	56,050	5 950	Very light
	2 B	"	"	3.11	3.21	9.98	4.10	40,400	69,650	6,070	
	7 A	"	"	3.09	3.22	9.95	4.04	11,730	51 090	5,134	Light
								30,847	Average	7,161	

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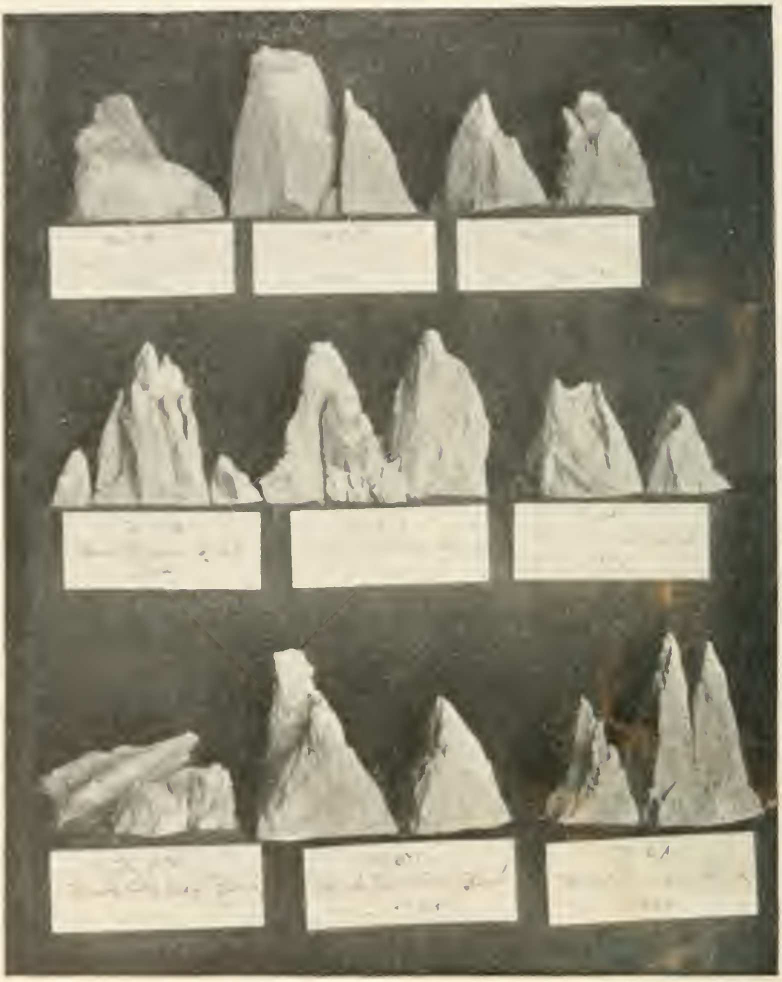
* This brick resisted 128,000 pounds. The machine was not overloaded beyond this point, and the estimated load for crushing of specimen was 130 000 pounds,



FRACTURES OF SETS OF FIRE BRICKS.

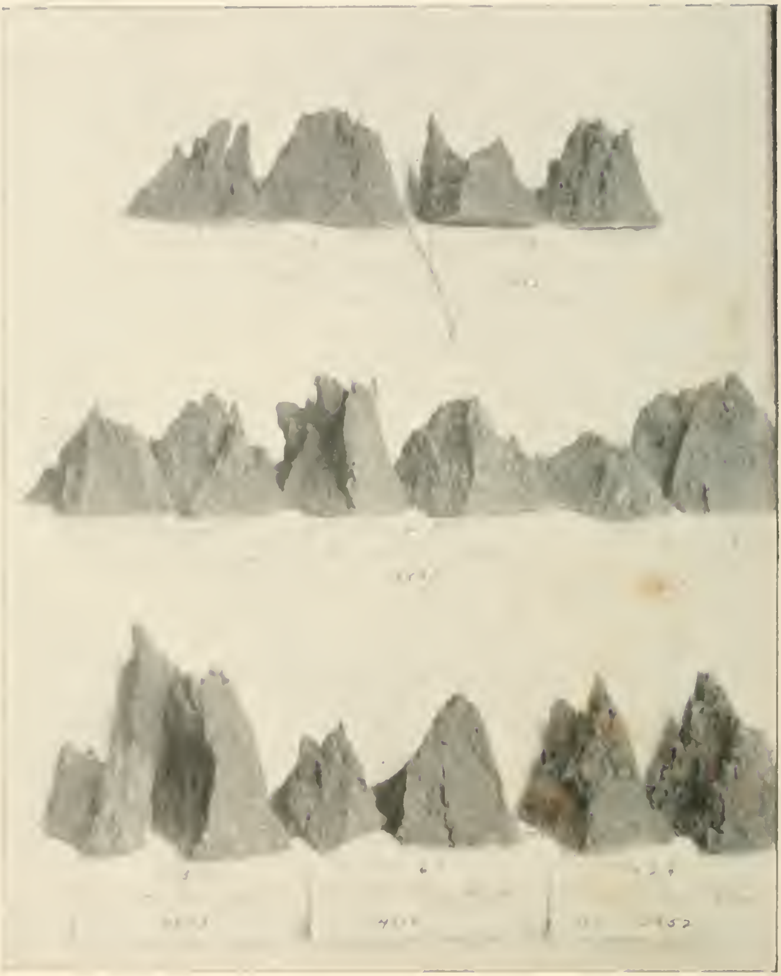
DATA OF COMPRESSION TEST OF PAVING BRICKS.

Material.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress —Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch —Pounds.	Spall.
Bannon Paving Brick. Made from fire clay obtained from different parts of Kentucky. Samples brownish red. Furnished by Bannon, ...	1 A	Unglazed,	8½ x 4 x 2½	2.40	2.51	6.03	4.20	10,000	42,800	7 098	Very light.
	1 B	"	"	2.40	2.82	6.76	4.19	23,450	29,715	4,395	Very h'vy.
	5 B	"	"	2.37	2.65	6.28	4.26	19,380	41,690	6,638	
		"									
								17,610	Average,	6,044	
Hallwood Block (Glazed Paving Brick). Made from fire clay obtained at Robbins, Tenn. Samples bluish brown. Furnished by Standard Construction Co., ...	1 B	Glazed,	9 x 4 x 2½	2.67	4.64	12.15	3.91	18,455	64,340	5,295	Deep.
	2 A	"	"	2.56	4.59	11.75	3 94	11,910	43,260	3,681	
	2 B	"	"	2.59	4.56	11.81	3.95	26,580	73,130	6,192	
	5 A	"	"	2 61	4 55	11.87	3.97	19,320	34,410	2,890	Deep.
	5 B	"	"	2.58	4 69	12.10	3 98	30,190	34,380	2,841	"
	6 A	"	"	2 6	4.62	12.01	4.06	19,960	39,500	3,288	"
	6 B	"	"	2.64	4 63	12.22	4.04	18,780	46,330	3,790	
	7 A	"	"	2.58	4.63	11.94	3.93	15,130	51,600	4,320	
	7 B	"	"	2.58	4 52	11.66	3.93	27,480	41,000	3,516	
								20,867	Average,	3,979	
"Riverside Paver." Made from plastic clay obtained at Middleport, Ohio. Samples bluish brown. Furnished by Grant R. B. Co., ...	2 AS	Glazed,	8 x 4 x 2½	2.51	2.62	6.73	3.90	7,030	21,930	3,259	
	1 AF	"	"	2.50	2.61	6.52	3.93	17,300	23,070	3,538	
								12,165	Average,	3,398	

Fractures of Sets of Fire Bricks.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

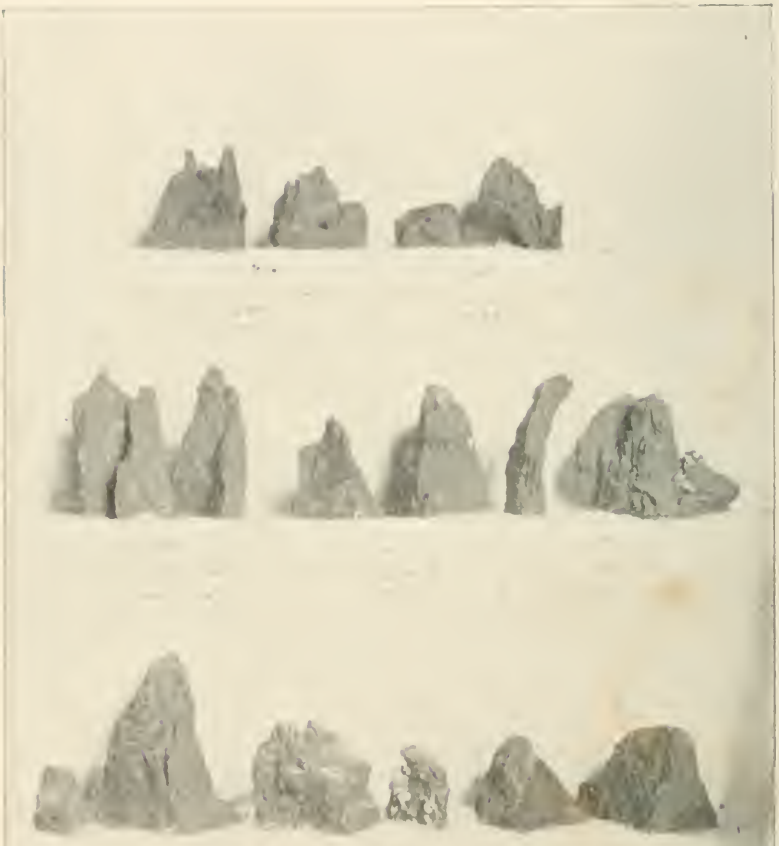
MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress —Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Ironton F. B. C. Paver. Made from a mixture of shale and fire clay obtained at Ironton, Ohio. Samples dark yellow-brown. Furnished by Lyttle & Dolan, ...	1 A	Glazed,	9x4x2½	2.68	3.70	9.91	4.25	45,580	62,050	6,261	Deep.
	3 A	"	"	2.62	3.85	10.08	4.43	16,760	80,710	8,006	Light.
	3 B	"	"	2.55	3.77	9.61	4.40	21,500	80,675	8,393	Very light.
	4 A	"	"	2.63	3.73	9.80	4.44	4,000	36,670	3,741	Heavy.
	4 B	"	"	2.63	3.89	10.23	4.51	21,460	42,760	4,179	Deep.
	5 B	"	"	2.60	3.77	9.80	4.47	16,700	67,030	6,840	Very light.
	6 B	"	"	2.65	3.77	9.99	4.38	4,320	92,225	9,222	Light.
								18,617	Average	6,663	
Mack Fire Clay Block. Made from fire clay obtained at New Cumberland, W. Va. Samples yellowish-brown. Furnished by Huntington Construction Co., ...	1 B	Unglazed,	9x4x3	3.15	4.72	14.87	4.06	118,430	124,220	8,347	Very light.
	1 A	"	"	3.2	3.66	11.71	4.04	27,830	60,610	5,175	Light.
	2 B	"	"	3.26	3.71	12.09	4.04	55,000	93,170	7,705	Deep.
	5 A	"	"	3.18	3.55	11.29	4.04	41,980	63,510	5,625	Light.
	5 B	"	"	3.14	3.72	11.68	4.05	13,970	73,550	6,297	
	6 A	"	"	3.18	3.60	11.45	4.02	36,640	82,470	7,202	Very light.
	6 B	"	"	3.14	3.73	11.71	3.98	25,825	74,540	6,365	Deep.
	7 A	"	"	3.14	3.7	11.6	4.07	53,930	82,590	7,119	
	7 B	"	"	3.18	3.69	11.73	4.04	51,275	64,135	5,468	
								47,209	Average,	6,589	



Fractures of Sets of Fire Bricks.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed —Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Robbins Paver—glazed. Made from fire clay obtained at Robbins, Tenn. Samples bluish brown. Furnished by Standard Construction Co., ...	1 A	Glazed,	8½x4x2½	2.66	4.38	11.65	4.28	18,020	50,810	4,361	Deep.
	1 B	"	"	2.66	4.25	11.3	4.27	18,270	60,260	5,333	"
	2 A	"	"	2 45	4.07	9.97	4.21	19,530	48,750	4,889	"
	7 A	"	"	2.53	4 35	11.	4.24	22,050	50,835	4,621	"
	5 A	"	"	2.45	4 24	10.38	4.23	14,200	52,780	5,084	"
	7 B	"	"	2.52	4.2	10.58	4.27	23,690	43,860	4,145	"
	2 B	"	"	2.48	4.28	10 61	4.21	14,410	33,090	3,119	"
	5 B	"	"	2.48	4.24	10.52	4.23	36,350	63,090	5,997	"
	6 B	"	"	2.49	4.22	10.5	4.26	17,270	57,840	5,508	Light.
								20,421	Average,	4,784	
Lexington Paving Brick Made from common clay obtained at Lexington, Ky. Samples dark red. Furnished by Lexington Brick Co , ...	2 B	Unglazed,	8½x4x2½	2½	4¼	10 62	$4\frac{5}{32}$	28,610	28,610	2,693	
	5 B	"	"	$2\frac{17}{32}$	4¼	10.76	$4\frac{5}{32}$	25.520	50,070	4,653	
	6 A	"	"	$2\frac{37}{64}$	4¼	10.96	$4\frac{5}{32}$	19,420	43,950	4,010	
	1 B	"	"	$2\frac{29}{64}$	4¼	10.42	$4\frac{7}{32}$	32,210	40,920	3,927	
	2 A	"	"	2½	$3\frac{15}{16}$	9.69	$4\frac{3}{16}$	16,280	32,480	3,352	
	5 A	"	"	$2\frac{9}{16}$	$4\frac{7}{32}$	10.81	$4\frac{3}{16}$	14,630	41,480	3,837	
	7 B	"	"	$2\frac{15}{32}$	$4\frac{5}{16}$	10.64	$4\frac{3}{16}$	27,460	33,410	3,140	
	6 B	"	"	$2\frac{19}{32}$	$4\frac{13}{64}$	10.88	$4\frac{3}{16}$	21,030	46,470	4,217	
	7 A	"	"	2½	$4\frac{7}{32}$	10 52	$4\frac{15}{64}$	33,490	35,950	3,417	
								24,283	Average.	3,694	



FRACTURES OF SETS OF FIRE BRICKS.

DATA OF COMPRESSION TEST OF PAVING BRICKS.

MATERIAL.	Laboratory Number.	Character of Surface of whole Brick.	Approximate Size of whole Brick in Inches.	Width at Right Angles to Line of Stress.—Inches.	Length at Right Angles to Line of Stress.—Inches.	Area at Right Angles to Line of Stress.—Square Inches.	Height Parallel to Line of Stress.—Inches.	Load at which Specimen began to Spall.—Pounds.	Load at which Specimen Crushed.—Pounds.	Crushing Strength per Square Inch.—Pounds.	Spall.
Grant Block. Made up almost entirely of plastic, or blue clay, obtained at Middleport, Ohio. Samples dark reddish brown. Furnished by Charles Spinks & Sons, ...	1 B	Glazed,	9x4x3	3.06	3.14	9.61	3.98	11,650	19,790	2,059	Heavy.
	2 B	"	"	3.04	3.03	9.21	4.07	13,250	19,885	2,158	"
	5 A	"	"	3.06	3.04	9.3	3.96	13,800	47,055	5,060	
	5 B	"	"	3.06	3.20	9.79	3.91	17,850	58,480	5,973	
	6 A	"	"	3.1	3.07	9.51	3.96	4,730	21,390	2,249	Light.
	6 B	"	"	3.09	3.16	9.76	3.98	21,400	37,490	3,841	"
	7 A	"	"	3.09	3.10	9.58	4.02	27,860	53,665	5,601	Deep.
	8 A	"	"	3.16	3.23	10.21	4.13	12,150	12,420	1,216	
	8 B	"	"	3.73	3.08	11.49	4.13	11,700	14,150	1,231	
								14,932	Average,	3,265	
"Kentucky" Paving Block. Made from a mixture of shale and plastic clay obtained at Portsmouth, Ohio. Samples reddish brown. Furnished by Chas. Spinks & Sons, ...	1 A	Glazed,	9x4x3	2.95	3.2	9.44	3.95	17,450	75,754	8,024	
	1 B	"	"	2.96	2.74	8.11	3.92	4,300	55,250	6,813	Very light.
	2 A	"	"	3.1	3.22	9.98	4.11	34,250	51,465	5,147	Heavy.
	6 A	"	"	2.96	2.73	8.08	3.94	14,920	64,679	8,005	
	6 B	"	"	2.96	2.93	8.67	3.95	52,400	81,760	9,430	
	7 A	"	"	2.97	2.97	8.82	3.88	9,310	81,960	9,293	
								22,105	Average,	7,785	

STRENGTH OF ICE.*

By C. W. Beach, A. M. Munn, and H. E. Reeves, Students in Class of '95, Civil Engineering Course, University of Illinois, Champaign, Ill.

THE comparative scarcity of published records giving experimental data concerning the strength of ice, suggested the desirability of further investigation of the subject. Only two records of compressive tests and one of tensile tests could be found; the first and more elaborate of these was executed by Col. William Ludlow, in 1880 and 1881, in connection with the construction of an ice harbor in the Delaware River, at Liston's Point, and the second tests were made by Fruhling, a German experimenter, about 1885.

Col. Ludlow's experiments, consisting of only eighteen compressive tests, gave a crushing strength, varying from 100 to 1,000 pounds per square inch, with an average of about 575. The ice used by him was of poor quality, a considerable portion being frozen snow, or frozen snow and ice combined. The temperature of the ice during the time of testing ranged from 25° to 31° F., while the temperature of the room varied from 29.6° to 68° F. The distribution of pressure was equalized by placing small blocks of white pine between the faces of the cubes and the upper and lower surfaces of the press. In conclusion, he says that "the minimum pressure requisite to crush ice of the clearest and most compact structure is 1,000 pounds per square inch; that ordinary clear ice, such as we get from the upper Delaware River, would, under certain conditions, resist a pressure of 700 pounds per square inch, and that ice in the condition that we should be likely to find it in the Delaware River, at Liston's Point, would crush with 400 or 450 pounds per square inch or less, from its gradual disintegration by exposure to the sun, air, and salt water."

Fruhling's experiments were made upon clear block ice tested at 23° F. He observes that "as the pressure was increased the cracks became more numerous until they went all through the test piece. As the pressure was further increased the height of the blocks began to diminish, and their cross-section to increase, until ultimately they were flattened out, never, however, giving way suddenly. The only stage in the flattening-out process, at which the pressure was accurately noted, was that at which the height of the block began to diminish." The pressure at which the height began to diminish perceptibly varied from 216 to 380 pounds per square inch, while the pressure at which cracks began to form varied from 60 to 200 pounds per square inch.

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* Extracts from *The Technograph*, No. 9.

The crushing tests of ice executed by the writers were made with a 100,000-pound Riehlé Testing Machine. The test pieces were sawn from blocks of ice, and their surfaces were planed down by means of a straight-edge made from a thin bar of iron. The cubes were crushed between sheets of heavy card-board, which served effectually to cushion the compressed surfaces. To prevent concentration of pressure, due to non-parallelism of opposite faces of the cube, or of the testing machine, the adjustable compression-plate shown in Fig. 1 was used.

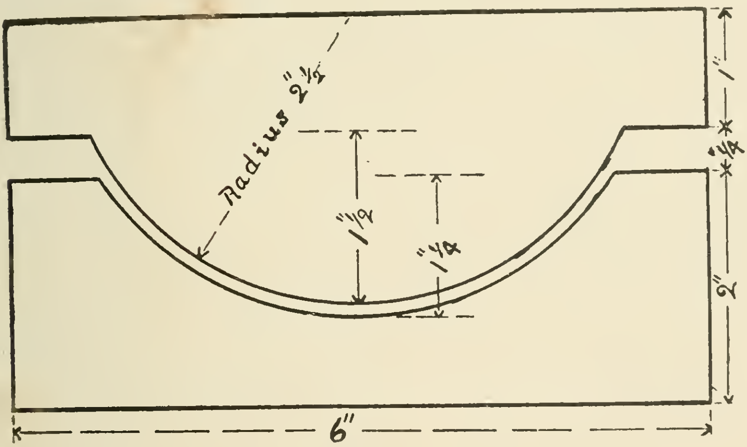

FIG. 1.

This device consists of two thick circular plates, six inches in diameter, the top face of the upper and bottom face of the lower being true planes. On the lower side of the upper piece is a solid spherical segment which fits into a spherical socket in the top of the lower casting. The surfaces in contact are smoothly and accurately shaped. By thorough lubrication of the segment an exceedingly delicate equalization is secured, even under the heaviest pressures.

At the time the experiments were undertaken natural ice had not formed of sufficient thickness to afford test cubes. A cake of artificial ice 14x14x30 inches was procured. From it were prepared four-

TABLE I.

DATA ON THE CRUSHING STRENGTH OF ICE CUBES.

Experiments Made at the Testing Laboratory of the University of Illinois.

No. of Test	Date	Kind of Ice	Temperature.			Dimensions of Specimens in Inches		Direction of Applied Pressure with Reference to Columnar Disintegration	Total Pressure at which Cracks first appeared, Pounds	Ultimate Crushing Strength in Pounds *		Remarks
			External Air	Laboratory	Ice at Time of Testing	Sides	Depth			Total	Per Sq. Inch	
			F.	F.	F.							
1	Dec. 27, '94.	Artificial.	12.[illegible]	2[illegible].7	25.[illegible]	4 x4¼	4¼	Parallel,	4,[illegible]	[illegible]	[illegible]	Gave away gradually; piece filled with iron rust and air bubbles.
2	"	"	"	"	"	"	4	Perpendicular,	[illegible]	[illegible]	[illegible].4	Broke suddenly with loud report; split in diagonal plane.
3	"	"	"	"	"	4¼x4¼	4	"	4,[illegible]	1[illegible]	7[illegible]	Gave way gradually; broke into small pieces when struck light blow with hammer.
4	"	"	"	"	"	4 x4¼	4	"	3,[illegible]	7,[illegible]	4[illegible]	Broke suddenly with report
5	"	"	"	"	"	4¼x4¼	4	"	[illegible]	1[illegible]	5[illegible]4	Specimen from corner of block; broke suddenly with report
6	"	"	"	"	"	4 x4¼	4¼	Parallel,	1,[illegible]	[illegible],700	[illegible]94	One side gave way before the other
7	"	"	"	27[illegible]	2[illegible]	4¼x4¼	4	" . . .	2,[illegible]	1[illegible],7[illegible]0	7[illegible]	At 2,000 pounds a crack appeared diagonally across the piece and extending through it.
8	"	"	"	"	"	4¼x4	4[illegible]	" . . .	2,000	12,1[illegible]	71[illegible]	Broke suddenly with report
9	"	"	[illegible]	"	"	2¾x5	4½	" . . .	1,000	[illegible]	42[illegible]	Specimens from corner of block; axes of columns on one side were vertical, and on the other side horizontal; diagonal line marking end of columns plainly visible.
30	Dec. 29, '94.	"	14.[illegible]	3[illegible]	14[illegible]	[illegible]¼x4¼	3[illegible]	Perpendicular,	5,20[illegible]	17,200	1,0[illegible]0	Gave way gradually.
31	"	"	"	"	"	4 x4	4	"	7,000	15,400	9[illegible]3	One corner chipped off; crushed suddenly.
32	"	"	"	"	"	3[illegible]x4	4	"	4,600	16,000	1,032	Centre and sides crushed out; broke suddenly with report.
33	"	"	"	"	"	4 x4	3[illegible]	Parallel, . . .	4,[illegible]00	5,400	[illegible]7	Broke suddenly on one corner with report.
34	"	"	"	"	"	3[illegible]x4⅛	4	" . . .	5,200	15,400	969	Gave way gradually.
35	"	"	"	"	"	6 x6	5[illegible]	Perpendicular,	10,000	34,600	962	Gave way gradually.
36	"	"	"	"	"	5¾x6	6	Parallel, . . .	7,200	25,700	775	Broke suddenly with loud report.

37	Dec. 29, '94,	Artificial,	14.9°	30.2°	14°	6 x6	5⅞	Perpendicular,	11,200	30,000	834	Broke suddenly with loud report.
38	"	"	"	"	"	6⅛x6	"	"	10,200	25,500	695	One side chipped off at 15,700; broke with report.
39	"	"	"	"	"	6 x6	"	Parallel, . . .	8,400	30,400	844	Broke suddenly with report.
10	Dec. 27, '94,	"	17.6°	23°	23°	6⅜x6½	6	Perpendicular,	12,000	29,800	719	Broke suddenly with report.
11	"	"	"	"	"	6¼x6½	5¾	"	11,600	27 400	623	Broke suddenly with report.
12	"	"	"	"	"	6½x6½	"	"	10,400	28,900	684	Gave way gradually.
13	"	"	"	"	"	6½x6¾	6	"	12,000	31,300	712	Broke suddenly with report.
14	"	"	"	"	"	6¼x6⅛	6⅛	Parallel, . .	12,200	17,500	456	Broke suddenly; piece failed at point where last ice was formed.
15	"	"	"	"	"	6½x6	6	" . . .	8,400	14,000	372	One-half the block failed, the other half did not crush. Failed as No. 14.
16	"	"	"	"	"	6 x6¼	6½	" . . .	10,200	28,500	759	Broke suddenly along diagonal plane from corner of original block to opposite.
17	"	"	"	"	"	6 x6½	6½	" . . .	6,200	24,000	615	Failed in same manner as No. 16. Line of failure plainly visible while under pressure.
40	Nov. 31, '94,	Natural,	21.2°	"	12.2°	4 x4	4	Perpendicular,	13,600	19,800	1,239	Broke suddenly with report.
41	"	"	"	"	"	"	3⅞	Parallel, . . .	13,000	23,700	1,608	Broke suddenly with report.
42	"	"	"	"	"	4 x4⅛	4⅛	Perpendicular,	. . . .	17,000	1,031	Broke suddenly without warning.
43	"	"	"	"	"	4⅛x4⅛	3⅞	Parallel, . . .	12,000	29,500	1,735	Broke suddenly. Cracking continued from 13,000 pounds on.
44	"	"	"	"	"	4 x3⅞	4	Perpendicular,	11,200	28,600	1,844	Similar to No. 43.
45	"	"	"	"	"	4¼x4	3⅞	Parallel, . . .	31,000	47,800	2,818	Broke suddenly with loud report. The boards under bearing surface crushed suddenly and probably caused premature failure.
46	"	"	"	"	"	4 x4⅛	3⅞	Perpendicular,	. . . .	12,000	728	Corner chipped off at 4,000 pounds. Evidently the bearing surface was imperfect.
47	"	"	"	"	"	3⅞x4⅛	4	Parallel, ...		31,600	1,975	At 28,000 pounds one corner chipped off. Broke suddenly with loud report.
48	"	"	"	"	"	4 x4⅛	4	Perpendicular,	. . . .	6,000	364	One corner chipped in preparing the piece. Failed suddenly.
49	Dec. 31, '94.	"	"	"	"	4¼x4	4	Parallel, . . .	1,300	26,300	1,649	Broke suddenly with report.
50	"	"	"	"	"	3⅞x4	4	Perpendicular,	10,000	13,200	852	Broke suddenly with report.
51	"	"	23°	"	"	4 x4	3⅞	Parallel, . . .	11,800	25,400	1,588	Broke suddenly with report.
52	"	"	"	"	"	4 x3⅞	4	Perpendicular,	. . . .	11,700	755	Broke suddenly without warning.
53	"	"	"	"	"	4 x4	3⅞	Parallel, . . .	22,000	30,500	1,905	Broke suddenly with report.
54	"	"	"	"	"	"	3¾	Perpendicular,	7,000	16,700	1,044	Corner chipped off at 3,500 pounds.
55	"	"	"	"	"	"	3⅞	Parallel, . . .	11,000	26,700	1,481	Broke suddenly with report.

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* The pressure was applied at an average rate of 10,000 pounds per minute.

teen 4-inch and thirteen 6-inch cubes, besides a number of small slabs. This ice was manufactured in the usual manner—that is, by immersing cans filled with water in cold brine. The ice first forms on the sides and bottom of the can and gradually freezes to the centre. Most of the impurities of the ice are thus concentrated at the centre of the cake, together with the air contained in the water.

The natural ice was obtained from a pond near by, and was quite free from air bubbles and impurities.

Ice, when subjected to pressure, is resolved into columns whose direction is normal to the surface which was in contact with the water while freezing. In natural ice these columns are parallel, hence the pressure is always applied perpendicular or parallel to them. By examining Table II it will be seen that those pieces tested with the pressure parallel to the columns developed about 77 per cent. greater strength than those tested with the pressure perpendicular to the column. Test piece No. 45 gave a very high result—2,818 pounds per square inch. This piece was remarkably clear and free from air bubbles. Rejecting it, the percentage is reduced to 63.

In artificial ice the columns extend from the side toward the centre, and from the bottom up. In cubes cut from the corners of a cake of artificial ice the columns were found to cross or intersect at right angles, and in such cubes the fracture is always in a plane cutting the diagonally opposite edges, the one half sliding on the other. It is possible, therefore, by selecting test pieces from different parts of the original cake, to obtain widely-varying results for the crushing strength. The great difference between the average crushing strength of natural and artificial ice is thus easily explained.

It was found that in homogeneous ice the phenomenon of failure by crushing is similar to that of cubes of sandstone tested in a like manner—that is, a cone is forced out from each of the four vertical sides.

A few small pieces of ice were crushed at 32° F., mainly for the purpose of observing the phenomena due to crushing at that temperature. In every such case the ice gave way gradually and changed form slowly. Ice at this temperature possessed quite a degree of plasticity and exhibited scarcely any of the phenomena shown by ice crushed at lower temperatures.

It would be of interest to make a series of tests through a great range of temperature and plot the results, so as to show the relation between strength and temperature.

TABLE II.

SUMMARY OF TABLE I.

	Pounds per square inch.
Mean strength of five 4-inch cubes of artificial ice, tested at 25.7° F.,	569
Mean strength of three 4-inch cubes of artificial ice, tested at 23° F.,	625
Mean strength of eight 6-inch cubes of artificial ice, tested at 23° F.,	617
Mean strength of all cubes of artificial ice, tested at 23° F.,	620
Mean strength of four 4-inch cubes of artificial ice, tested at 14° F.,	1,011
Mean strength of five 6-inch cubes of artificial ice, tested at 14° F.,	822
Mean strength of all cubes of artificial ice, tested at 14° F.,	906
Mean strength of all cubes of artificial ice tested,	560
Mean strength of seven 4-inch cubes of natural ice, with direction of pressure perpendicular to columns, tested at 12.02° F.,	1,070
Mean strength of eight 4-inch cubes of natural ice, with direction of pressure parallel to columns, tested at 12.2° F.,	1,845
Mean strength of all cubes of natural ice tested,	1,451

Experiments were also made upon the crushing strength of slabs of ice, the results of which are shown in Tables III and IV:

TABLE IV.

SUMMARY OF TABLE III.

	Pounds per square inch.
Average of all natural ice slabs tested,	777
Average of the four most nearly perfect slabs of natural ice,	932
Average of all slabs of artificial ice tested,	718
Average of nine most nearly perfect slabs of artificial ice tested,	763

TENSILE STRENGTH.

The tests for tensile strength were made with a Riehlé cement testing machine. The briquettes were made by placing the brass cement briquette molds in a shallow pan of water and allowing it to freeze. The briquettes were easily removed from the molds by allowing a stream of water to flow over them for a short time, their cross-section not being sensibly reduced by this operation. Nos. 21, 22, 23, and 27 were shaved to a less cross-section than one square inch. By reducing the cross-section, and thereby the ultimate strength, a greater and more nearly correct value of the unit tensile strength at that temperature was obtained. A large per cent. of the briquettes broke in the grips, due to cross-stresses induced by partial crushing. It would seem from the experiments that a slight difference in temperature makes considerable difference in the tensile strength of ice.

From these experiments the following conclusions may be drawn:

TABLE III.

DATA ON THE CRUSHING STRENGTH OF ICE SLABS

Experiments Made at the Testing Laboratory of the University of Illinois

No. of Piece	Date	Kind of Ice	Temperature: External Air	Temperature: Laboratory	Temperature: Ice at Time of Testing	Dimensions of Specimens in Inches: Sides	Dimensions of Specimens in Inches: Depth	Direction of Applied Pressure with Reference to Columnar Disintegration	Total Pressure at which Cracks first appeared, Pounds	Ultimate Crushing Strength in Pounds: Total	Ultimate Crushing Strength in Pounds: Per Sq. Inch	Remarks
			F	F	F							
[illegible]	Dec [illegible] '94	Artificial,	17°	[illegible]	[illegible]	[illegible]x4¼	2¼	Perpendicular,	5,[illegible]	[illegible]	1,0[illegible]	Resolved into columns perpendicular to direction of force
[illegible]	"	"	"	"	"	4¼x4	2[illegible]	"	2,400	7,[illegible]	4[illegible]	Broke suddenly with report. Columns parallel to force.
[illegible]	"	"	"	"	"	4 x4	2[illegible]	"	1,400	7,500	4[illegible]	Broke suddenly with report
[illegible]	"	"	"	"	"	4 x4	1[illegible]	"	3,[illegible]	13,[illegible]	7[illegible]	Broke suddenly with report
[illegible]	"	"	"	"	"	[illegible]x3¼	1[illegible]	"	2,[illegible]	20,4[illegible]	915	Failed gradually
[illegible]	"	"	"	"	"	[illegible]¼x5½	1[illegible]	"	2,[illegible]	13,400	74[illegible]	Failed gradually
24	"	"	"	"	"	2[illegible]x5½	2¼	"	3,[illegible]	4,8[illegible]	[illegible]	Broke suddenly. Centre of block full of air bubbles
[illegible]	Dec [illegible]	"	12[illegible]	"	"	2 x3	1[illegible]	"	2,2[illegible]	5,[illegible]	[illegible]3	Broke suddenly with report.
[illegible]	"	"	"	"	"	4 x4	1[illegible]	"	2,8[illegible]	13,000	743	Broke suddenly with report.
[illegible]	"	"	"	"	"	4 x4[illegible]	1[illegible]	Parallel, . . .	2,2[illegible]	13,[illegible]	[illegible]	Broke suddenly with report.
[illegible]	"	"	"	"	"	4¼x5[illegible]	1[illegible]	" . .	[illegible]	21,500	[illegible]13	This piece came from centre of block and was full of rust and air bubbles.
[illegible]	"	"	"	"	"	1¼x[illegible]	2	" .	4,200	1[illegible],[illegible]00	5[illegible]1	Broke suddenly. Full of rust and air bubbles
5[illegible]	Dec 31, '94	Natural,	[illegible]	"	12.2°	6 x4	1[illegible]	Perpendicular,	[illegible]	35,[illegible]	1,4[illegible]	Broke suddenly.
57	"	"	"	"	"	5¾x4	1[illegible]	"	[illegible],000	17,000	7[illegible]	Broke suddenly. Flaw in piece
58	"	"	"	"	"	4 x5[illegible]	1[illegible]	"	10,000	25,800	1,0[illegible]	Failed gradually.
59	"	"	"	"	"	4 x6	1[illegible]	"	. .	11,000	45[illegible]	Broke suddenly. Specimen imperfect.
60	"	"	"	"	"	4 x5[illegible]	1[illegible]	"	7,[illegible]	[illegible]1,700	724	Failed on one side.
61	"	"	"	"	"	4 x6	2	"	4,800	10,300	4[illegible]	Broke suddenly with report.
62	"	"	"	"	"	4 x6	1¼	"	4,000	17,800	74[illegible]	Broke suddenly with report.

1. Ice, when subjected to pressure, is resolved into columns normal to the natural surface.

2. The greatest strength is obtained when the direction of applied pressure is parallel to the columns, and least when perpendicular to them.

3. Ice subjected to pressure at 32° F. readily changes form.

4. Variations in temperature produce a perceptible influence on both compressive and tensile strength of ice.

TABLE V.

DATA ON TENSILE STRENGTH OF NATURAL ICE.

Experiments made at the Testing Laboratory of the University of Illinois.

No. of Piece.	Date.	Temperature.		Section in Inches.	Ultimate Pressure in Pounds.	Tensile Strength in Pounds per Square Inch.	Location of Break.
		External Air.	Ice at Time of Testing.				
1	Dec. 28, '94, . .	13.1° F.	19.4° F	1x1	102	102	Centre.
2	“ . .	“	“	“	132	132	Imperfect.
3	“ . .	“	“	“	179	179	Centre.
4	“ . .	“	“	“	163	163	Centre.
5	“ . .	“	“	“	239	239	Centre.
6	“ . .	“	“	“	228	228	Upper grip.
7	“ . .	“	“	“	174	174	Lower grip.
8	“ . .	“	“	“	191	191	Lower grip.
9	“ . .	“	“	“	200	200	Lower grip.
10	“ . .	“	“	“	218	218	Lower grip.
11	“ . .	“	“	“	156	156	Lower grip.
12	“ . .	“	“	“	215	215	Centre.
13	“ . .	“	“	“	165	165	Centre.
14	“ . .	“	“	“	200	200	Lower grip.
15	“ . .	“	“	“	208	208	Centre.
16	“ . .	“	“	“	126	126	Centre.
17	“ . .	“	“	“	178	178	Centre.
18	“ . .	“	“	“	221	221	Lower grip.
19	Dec. 31, '94. . .	21.2° F.	23° F .	“	120	120	Centre.
20	“ . .	“	“	“	110	110	Lower grip.
21	“ . .	“	“	1x⅞	167	175	Lower grip.
22	“ . .	“	“	⅞x⅞	196	256	Lower grip.
23	“ . .	“	“	1x⅞	138	158	Lower grip.
24	“ . .	“	“	1x1	120	120	Upper grip.
25	“ . .	“	“	“	106	106	Centre.
26	“ . .	“	“	“	153	153	Centre.
27	“ . .	“	“	1x⅞	122	139	Centre.
28	“ . .	“	“	1x1	124	124	Lower grip.
29	“ . .	“	“	“	160	160	Upper grip.
30	“ . .	“	“	“	167	167	Centre.
31	“ . .	“	“	“	159	159	Lower grip.
32	“ . .	“	“	“	148	148	Centre
33	“ . .	“	“	“	118	118	Lower grip.
34	“ . .	“	“	“	120	120	Lower grip.

TABLE VI.

SUMMARY OF TABLE V.

	Pounds per square inch.
Average of briquettes tested at a temperature of 10.4° F. which broke in centre,	184
Average of briquettes tested at a temperature of 23° F. which broke in the centre,	139
Average of briquettes tested at 10.4° F. that broke in the grips,	191
Average of briquettes tested at 23° F. that broke in the grips,	150
Average of all briquettes tested that broke in the centre,	160
Average of all briquettes tested that broke in the grips,	169
Average of all briquettes tested at 19.4° F.,	183
Average of all briquettes tested at 23° F.,	146
Average of four pieces tested with a less cross-section than one square inch at 23° F.,	182
Average of all briquettes tested,	165

The results of five tests made by Fruhling at a temperature of 23° F. gave an average tensile strength of 189 pounds per square inch. The cross-section of his specimens was 0.77 square inches.

DR. ROBERT H. THURSTON.

Pioneer in Scientific Experimental Engineering.

TO Dr. Robert H. Thurston, director of Sibley College, the School of Mechanical Engineering of Cornell University, whose portrait appears in this number, and whose originality, thoroughness of investigation, and prolific writing has made his name famous throughout the engineering world, is due the honor of having contributed more in the last twenty years toward a better knowledge of the physical properties of engineering materials, in all possible forms of their application, than has been accomplished in any half-century before.

Robert H. Thurston, born in Providence, R. I., October 25th, 1839, of a family of the old Viking stock, was the son of Robert Lawton Thurston, a distinguished inventor and mechanic, who founded what is now the Providence Steam Engine Co. The son inherited his father's talents, but confined himself more to the theoretical than to the practical side of engineering. His early training was received in the public schools of Providence, where, during holidays and vacations, he picked up much valuable practical experience in his father's works. At the age of sixteen he entered the class of '59 at Brown University, in which year he received the degrees of Ph. B. and C.E., and, later, those of M. A. and LL. D.

In 1861, after a short business experience with his father, Dr. Thurston entered the Engineer Corps of the United States Navy, and served with distinction throughout the war, attaining, in 1865, the rank of First Assistant Engineer, when he was detailed to the professorship of natural and experimental philosophy in the United States Naval Academy. His success as a teacher of science was remarkable, and in 1870 he was called to the chair of Mechanical engineering at the then newly-founded Stevens Institute of Technology, Hoboken, where, in 1871, he organized the first mechanical laboratory founded as a department of education in a school of mechanical Engineering. It was here that he discovered the exaltation of the normal elastic limit in iron and steel, and carried on the first and only complete systematic investigation of the strength and ductility of the copper-tin-zinc alloys, discovering, in 1873, the maximum alloys of the Kalchoid series. It was here, also, that he first discovered and investigated the variation due to orthogonal strains in the elastic limit of metals, conducted the first investigation of the principal methods of strain on timber, discovered the fact of an increased power of resisting stress which was developed in iron and steel by their subjection to a strain which produced distortion beyond the elastic limit and gave them set, and here that he wrote most of the papers on the strength of materials that have since given him such a world-wide reputation.

Dr. Thurston spent the summer of 1873 at Vienna as member of the International Jury of the United States Scientific Commission. He was also a member of the committee of the American Society of Mechanical Engineers promoting the Centennial Exposition of 1876. He was given an "*Ehren Diplom*" at Vienna, and a medal and diploma at Philadelphia for his autographic testing machine. He was the first President of the American Society of Mechanical Engineers, three times Vice-President of the American Association for the Advancement of Science, Vice-President of the British Association, and Vice-President of the American Institute of Mining Engineers. He is a member of the principal European Scientific and Engineering Societies, Officer de l'Instruction Publique de France, member of the military order of the Loyal Legion, member of the American Society of Civil Engineers, and honorary member of the Franklin Institute.

So eminently successful was Dr. Thurston's career that in 1885 he was invited to assume the directorship of the Sibley College of Mechanical Engineering, then proposed to be organized at Cornell University, which position was created for him. The evolution of the college had been rapid, its student-body having increased over a thousand per cent. in ten years. Under the Doctor's masterful directorship it stands to-day one of the first schools of mechanical engineering in the country. In 1890 and in 1895, at the expiration of five and of ten years of services, respectively, he surrendered his plenipotentiary power to the trustees of the University; but it was not accepted, and he was requested to remain and to continue to exercise the powers originally conferred upon him.

Outside his college work Dr. Thurston always had a professional practice, and has continued to publish books, reports, and technical papers, bringing up the number of his writings to above two hundred and fifty. Among his best known works are: *A History of the Steam Engine*, *A Manual of the Steam Engine*, *Materials of Engineering*, etc., etc.

In the summer of 1889 he was called to act upon the International Jury held in Paris, and was made by the French government "Officer de l'Instruction Publique," receiving also a double nomination by the Jury and by the U. S. Commission as Officer of the Legion of Honor. He was also on the International Jury at Chicago in 1893, and was assigned to special duty in direct connection with the office of the committee on awards.

Dr. Thurston's large experience of the world, keen insight into human nature, gracious manner, and great kindness of heart admirably fit him for the position he holds. He has ever a kind word for the students in difficulties, and a warm hand-clasp for those he meets in after years, which has won for him the deep and lasting esteem of the thousand of students who have had the privilege of being guided by and knowing a man of his unusual attainments.

STEEL CASTINGS AND MALLEABLE IRON.

By C. H. Benjamin, Professor of Mechanical Engineering, Case School of Applied Science, Cleveland, Ohio.

I HAVE noticed of late some discussion in the technical journals with regard to the peculiarities and relative merits of so-called steel castings and malleable or annealed castings.

I have from time to time had occasion to conduct numerous tests on the metals included under the above heads, and think that some of the results may be of sufficient interest for publication.

Steel castings are used quite generally by machinery manufacturers, instead of wrought iron or bronze, in places where cast iron is inadmissible, but I think they are used without any definite idea of their strength or fitness.

I also suspect that steel castings are often malleable castings under another name, and are neither better nor worse than the latter.

To procure material for tests patterns suitable for test, pieces were made and sent to the different manufacturers, who advertise to make small steel castings for the trade.

Six tension pieces and six compression pieces were thus obtained of each of four firms, one doing business in Massachusetts, one in New York, and two in Pennsylvania. The castings were obtained through outside parties and nothing was said about testing them, as the idea was to get fair samples of castings supplied to the trade.

I will denote the different series as A, B, C, and D, without giving the names of the makers. The tension pieces in each series were of standard shape, eight inches between marks, and about 3/8x1.2 inches in cross-section.

The compression pieces were cylindrical, two inches long and about three-fourths of an inch in diameter.

In general these specimens may be considered as representing the character of the steel in small castings made by the different firms represented.

Three tension and three compression pieces in each series were tested in a rough condition, just as they came from the foundry or the annealing furnace, while the other three of each kind were finished by removing the scale to about the same depth as in ordinary machine finishing. The extensometer used in making the tests was one invented by the writer, and illustrated in the January issue of this magazine, and the tests were all made on a Riehlé machine. Table I gives a summary of the experiments as far as completed.

The three sets, A, B, and D, were probably made of a steel comparatively high in carbon and were then softened by some sort of an annealing process, as is the case with malleable castings. This is evidenced by the comparatively sharp corners on these castings, showing a high temperature in pouring, and by a thin skin of softer metal on the outside. This latter peculiarity is plainly shown in the fractures of the tension pieces.

The castings in series C showed none of these characteristics, and were probably a low grade steel not subjected to any annealing. They were harder and stronger than the others, less uniform in character, and did not possess much ductility.

The rounded corners showed that the steel was hardly thin enough to run in such thin castings. One manufacturer, to whom application was made, failed entirely from a similar cause.

The figures in the table represent in each case the average results from two or three experiments.

The elastic limit was determined by taking numerous readings from the extensometer, plotting the usual elastic curves, and thus locating by inspection the points where a change occurred in the rate of extension or compression.

The modulus of elasticity was calculated from the stress and distortion at the elastic limit.

In series A and B the elastic limit is about one-half the ultimate strength. In series C and D there is such a lack of uniformity in the elasticity as forbids any attempt at averaging, and this fact alone should condemn them for use in machinery.

The percentage of elongation is seen to be very small, the material in this respect resembling cast iron rather than steel. The contraction of area was too slight to be measured.

One interesting phenomenon was noticed during the elongation. A strip of metal along the centre line of the test piece seemed to have been less affected by the annealing than the parallel edges, and to be less ductile, so that minute cracks would be seen extending across this strip at intervals, some time before the fracture of the specimen as a whole.

The failure of the compression specimens was in every case by bending out of the vertical in a curve of double flexure, and finally tipping over, so that no values of maximum strength could be obtained. The pressure in some instances was carried as high as 135,000 pounds per square inch.

The values of the elastic limit were determined in the same manner as with the tension pieces, and the curves plotted are somewhat similar, save that the elastic is very low as compared with the ultimate strength of the metal. The pieces showed no signs of fracture during the tests.

TENSION.

Series No.	Rough or Finished.	Length. Inches.	Breadth, Inches.	Thickness. Inches.	Area of Section.	Elastic Limit.	Ultimate Strength.	Elongation.		Modulus of Elasticity.
								Inches.	Per Cent.	
A	Rough,	8	1.227	.389	.478	17,060	38,940	.09	1.12	34,510,000
	Finished,	8	1.157	.307	.355	19,480	39,600	.04	0.5	34,919,000
B	Rough,	8	1.233	.392	.484	18,640	38,490	.17	2.15	20,643,000
	Finished,	8	1.165	.311	.363	17,490	33,990	.13	1.6	31,536,000
C	Rough,	8	1.234	.385	.476	. . .	55,320	.08	1.	24,263,000
	Finished,	8	1.114	.317	.354	. . .	75,130	.07	0.9	31,680,000
D	Rough,	8	1.23	.386	.475	. . .	35,180	.06	0.8	27,205,000
	Finished,	8	1.19	.33	.394	. . .	32,600	.04	0.5	23,795,000

COMPRESSION.

Series No.	Rough or Finished.	Length. Inches.	Diameter. Inches.	Area of Section.	Elastic Limit.	Modulus of Elasticity.
A	Rough,	2	.7744	.471	34,630	4,105,000
	Finished,	2	.7496	.441	31,940	5,097,000
B	Rough,	2	.7902	.490	30,770	4,934,000
	Finished,	2	.687	.371	25,610	6,791,000

Series C and D were not tested for compression.

One object of these experiments was to determine the effect of removing the scale on the strength of the metal, but I must confess that the results were rather disappointing, as far as arriving at any exact conclusion is concerned.

By reference to the table it will be seen that the specimens in series A were not materially affected in strength by finishing, that those in series B and D became weaker and less ductile by removing the outside skin, showing that the best metal was on the outside, and, finally, that the specimens in series C became apparently stronger by finishing.

I am inclined, however, to attribute this latter result to a lack of uniformity in the metal, as the specimens in series C were very deficient in this respect.

A series of experiments were made to determine the shearing strength of the metal in series A and B, the average results being as follows:

Series A, ultimate shearing strength, 56,700.
Series B, ultimate shearing strength, 42,900.

The conclusions to be drawn from these few experiments may be summed up as follows:

1. That ordinary small steel castings, such as may be purchased in the market, have an ultimate tensile strength varying from 33,000 to 44,000 pounds per square inch, or an average of about 37,500 pounds.

2. That the elastic limit may be safely taken at fifty per cent. of the ultimate tensile strength.

3. That the value of the modulus of elasticity varies from 20,000,000 to 35,000,000, with an average value of 28,500,000.

4. That the elastic limit of compression varies from 25,000 to 35,000 pounds per square inch, with an average value of 30,000 pounds.

5. That the effect of removing the scale on the strength of a steel casting depends entirely on the nature of the treatment to which the metal has been exposed in casting and in annealing.

MALLEABLE CASTINGS.

The results which I have obtained from ordinary malleable castings are so nearly the same as to need no special comment, and the appearance of the fractures is much the same. I have summarized the results of a number of tests as follows:

TENSILE STRENGTH OF MALLEABLE IRON.

Ultimate (average of 12 tests), ...	38,270 pounds.
" (average of 10 tests), ...	36,160 "
Elongation (average of 12 tests), ...	0.97 per cent.
" (average of 10 tests), ...	1.2 per cent.

SHEARING STRENGTH.

Ultimate (average of 7 tests), ...	42,560 pounds.
" (average of 5 tests), ...	43,100 "

These experiments were made at different times on two different sets of samples.

THE MOBILITY OF MOLECULES OF CAST IRON.*

By Alex. E. Outerbridge, Jr.

IT has been generally accepted as a fact that cast iron under the influence of repeated shocks becomes brittle, and will finally break under a blow which otherwise it would have withstood.

It will probably surprise metallurgists, therefore, to learn that experiment disproves the supposed fact and establishes exactly the opposite condition.

The result of about a thousand tests of bars of cast iron of all grades, from the softest foundry mixtures to the strongest car-wheel metal, enables me to state with confidence that within limits cast iron is materially strengthened by subjection to shocks or repeated blows.

It is very well known that the usual process of annealing castings —such, for example, as car-wheels—increases their strength by releasing cooling strains.

It is not well known, if known at all—prior to this announcement—that the molecules of cast iron are capable of movement (for they do not touch each other †) without the necessity of heating the castings, and they can thus re-arrange themselves in comfortable relation to their neighbors, and relieve the over-crowding near the surface of the casting, or, in more technical words, a molecular annealing may be accomplished at ordinary temperatures which will release the strains in the castings, precisely as does annealing by slow cooling in heated pits or ovens. Such a surprising statement should not be made without sufficient data to establish its correctness beyond cavil, since it is contrary to former belief, certain to be questioned and properly so.

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* Read at the Pittsburg meeting of the American Institute of Mining Engineers, February 20th, 1896.

† In order to comprehend the modern ideas of the nature of matter, we should try to realize that the molecules composing even the most dense solid substances with which we are familiar—such as gold, platinum, etc.—are not in contact and are free to move within certain well-defined limits. Lecture on "Matter," *Journ. Franklin Inst.*, September, 1885, v. 90, p. 184.

Before proceeding to give a record of the experiments which have been made, and which can be readily repeated by any one, a brief history of the origin of the first observation leading thereto may be interesting.

I noticed in the year 1883 (being at that time engaged in metallurgical work at a large car-wheel establishment), that chilled cast iron car-wheels rarely cracked in ordinary service after having been used for any considerable time; if wheels did not crack when comparatively new they usually lasted until worn out or condemned for other causes. No application was made of this observation at that time further than to institute a careful investigation of the condition of the annealing ovens when some new wheels were returned cracked, under the supposition that the wheels were not well annealed, and an equally careful revision of the iron mixture to ascertain whether the fault lay therein.

In 1894 a large number of "transverse test bars" (1 inch square, 15 inches long) accumulated in the foundry of Wm. Sellers & Co., Incorporated, and to expedite the cleaning of sand from their surfaces, they were all thrown into an ordinary "tumbling barrel," with other castings, and knocked about for several hours. When these test bars were broken upon the transverse testing machine and the records tabulated, I noticed, with surprise, that the average strength of the entire series was considerably higher than was usual with similar iron mixtures.

This difference was fortunately sufficiently marked to cause a careful inquiry, first into the condition of the testing machine, then as to the chemical composition of the metal in the bars; the machine was found in good order, the metal was normal. A card-pattern was then made upon which twelve test bars could be molded side by side in one flask and poured from one runner.

Six of these bars were placed in the tumbling barrel and the other six were cleaned of adhering sand with an ordinary wire brush; the twelve bars were broken upon the machine. ALL OF THE BARS WHICH HAD BEEN SUBJECTED FOR ABOUT FOUR HOURS TO INCESSANT BLOWS IN THE TUMBLING BARREL WERE STRONGER THAN THE

COMPANION BARS, the actual gain varying from 10 to 15 per cent.; this metal was soft foundry iron.

These tests were repeated on several consecutive days, with similar results, while various theories were being suggested and clews "run out" to detect the hidden cause of this strange fact.

One plausible explanation offered was that the rubbing of the bars together in the tumbling barrel slightly rounded the corners, and thus prevented a starting point for a "check" or break of the bar under the strain in the testing machine.

This theory was soon overthrown by tests. The corners of six bars were rounded by filing, the companion bars were not filed, all of the bars were cleaned with a wire brush and broken upon the transverse testing machine; there was no apparent gain in strength in the bars with rounded edges.

Round test bars (1⅛ inches diameter, 15 inches long,) were then poured from one ladle of iron; some of these were cleaned in the tumbling barrel, and all that were so treated proved to be much stronger than the companion bars, which were merely cleaned with a wire brush.

This process of eliminating false theories was continued, until finally a new explanation occurred to me, and simultaneously a convincing test of its accuracy suggested itself.

The explanation is indicated in the title of this paper, viz., "The Mobility of Molecules of Cast Iron" at ordinary temperature when subjected to repeated shocks.

The crucial test referred to was in subjecting six bars to 3,000 taps each with a hand hammer upon one end only of each bar. All of these bars so treated showed a gain in strength equivalent to the gain exhibited by bars which had been subjected to blows over the entire surface for several hours in the tumbling barrel.

Here was a new revelation of scientific interest to the metallurgist, and suggesting to the founder the possibility of annealing castings at ordinary temperature by availing himself of this molecular mobility, it also proves that he has for many years been unconsciously accomplishing this beneficial result—at least partially and irregularly—by tumbling small castings in a revolving barrel merely for the purpose of conveniently cleaning them from adhering sand.

Another interesting fact is incidentally brought out in this investigation, viz., that the strain caused by cooling and consequent weakening exists even in the smallest castings, where we would naturally expect that the cooling would be practically uniform throughout the section; also, that even in bars of uniform section, such as 1-inch test bars, the weakening by cooling strains sometimes amounts to more than 10 per cent. of the ultimate stress. Repeated tests show that 1½-inch bars, in which the fracture is comparatively uniform to the eye throughout the section, are subject to the same law.

Other tests show that the comparative difference in transverse strength between bars which have been hammered on their ends, or otherwise subjected to the process of molecular annealing by vibration when cold, and companion bars cast in the same flask not so improved, depends, to a certain extent, upon the number and force of the blows, and to a still greater degree upon the grade of cast iron tested. For example:

1. Greater relative difference is found in hard mixtures (or strong iron) than in soft mixtures or weak iron.

2. Greater relative difference is found in 1-inch bars than in 1½-inch bars, and somewhat greater difference in 2-inch bars than in 1-inch bars.

IMPACT TESTS.

The foregoing achievements having been repeated sufficiently often to satisfy me of their absolute reliability (and really remarkable uniformity), a new series of tests was commenced for the purpose of ascertaining how many blows were required and approximately what force was needed to accomplish the desired object of relieving cooling strains. A new machine was constructed for this purpose, and light was soon thrown upon these questions, while still other important questions were suggested and answered by the use of the same machine.

The impact machine at first used was an old one, and consisted of a weight fastened to an arm swinging in a graduated arc. The friction of the pivot and the crude construction of the machine precluded certain or even approximately sure results as to the force of the blow delivered.

The new machine consisted of a frame or yoke marked in inches and a wedge-shaped weight adapted to the size of the bars to be tested, which was raised perpendicularly to any desired number of inches, and when released fell by gravity in free space, striking the bars in the centre between the supports, which were 12 inches apart. A 14-pound weight was adopted for testing 1-inch bars.

Impact testing machines have long been used, and car-wheels are accepted or condemned upon tests made upon such machines. It has always been maintained that each blow of the "drop" weakened the casting, and the final blow was only a record of the residual cohesion remaining in the metal after previous blows had proportionately weakened it.

In the case of a thoroughly annealed car-wheel this reasoning may be sufficiently correct, but as applied to impact testing machines used for testing unannealed bars the argument is absolutely fallacious. The impact testing machine is itself a means of molecularly annealing test bars, as I will now proceed to demonstrate.

IMPACT EXPERIMENTS.

Six of the 1-inch square test bars, cleaned with the wire brush, were broken upon the impact machine by dropping the weight from a sufficient height to break each bar at the first blow. The six companion bars, also cleaned with the brush, were then, in turn, subjected to blows numbering from 10 to 50 each of the same drop weight, falling one-half the former distance, these blows being insufficient to break the bars. The weight was then permitted to fall upon each of these bars, in turn, from the height at which the six bars previously tested were broken on first blow. Not one bar broke. Two, three, six, ten, and in one case fifteen, blows of the same drop, from the same extreme height, were required to break these bars. In another similar case the weight was dropped once from the former maximum height, then raised by inches until four more blows, each being 1 inch higher than the last, were delivered before breaking the piece. Subsequent tests gave still greater gains in strength.

The next experiment with the impact machine was designed to test molecularly annealed bars from the tumbling barrel, in comparison with untreated companion bars, under one heavy blow. It was found that a blow of sufficient force to break the unannealed bars with one fall of the weight must be repeated from five to twenty times (depending mainly upon the nature of the iron mixture) to break the molecularly annealed companion bars.

By careful experiment, in the manner previously noted, the ultimate strength of the bars which had not been through the tumbling barrel could be increased by successive slight blows upon the impact machine to an equality with their companions.

The experiments here related in a running conversational narrative form a part of the daily records of the metallurgical work at the foundry of William Sellers & Co., Incorporated, Philadelphia, and the aggregate number tabulated is very large, indeed. All of the tests corroborate to the fullest degree the statements made, and they are susceptible of repetition and confirmation by any one interested in work of this character. They form part of a long series of investigations (extending over a period of 15 years) upon "the relation between the physical nature and chemical composition of cast iron." They have served to throw some light upon hitherto obscure phenomena in the design, construction, etc., of castings, and as it

TABLE I.—Strength and elasticity of test bars (A) of various kinds of cast iron, unannealed, and cleaned only with a wire brush, and (B) similar bars, molecularly annealed by repeated shocks in a tumbling barrel or by tapping with a light hammer.

A CLEANED WITH A WIRE BRUSH. RESULTS FROM BARS UNANNEALED.		B RESULTS FROM COMPANION BARS "MOLECULARLY ANNEALED."		REMARKS.
BREAKING STRAIN, POUNDS.	DEFLECTION, INCHES.	BREAKING STRAIN, POUNDS.	DEFLECTION, INCHES.	
2,350	.13	2,850	.14	Close-grain iron.
2,025	.12	2,300	.14	Open "
2,125	.13	2,275	.14	" "
2,275	.13	2,400	.14	" "
2,525	.14	2,850	.15	Close "
2,175	.13	2,500	.15	Open "
2,100	.13	2,375	.14	" "
2,025	.12	2,300	.14	" "
2,775	.14	2,900	.15	Close "
2,150	.13	2,250	.13	Hammered on end of bar.
2,550	.14	2,025	.15	" " "
3,000	. .	3,200	. .	Round bars $1\frac{1}{8}$ inches diameter.
3,000	. .	3,150	. .	Hammered on end of bar.
2,150	. .	2,450	. .	Round bars $1\frac{1}{8}$ inches diameter.
2,100	.13	2,425	.15	Open grain iron.
2,100	. .	2,400	. .	Round bars $1\frac{1}{8}$ inches diameter.
2,050	.12	2,400	.14	Open-grain iron
2,875	.14	3,100	.15	Close "
2,175	.13	2,500	.15	Open "
2,150	.13	2,350	.13	" "
2,675	.13	3,000	.14	Close "
2,775	.14	3,300	.15	" "

is believed that they contain the germ of a new scientific discovery valuable in its principle to all workers in these fields, these brief notes are presented to the Institute of Mining Engineers in response to the invitation of its Secretary, and through the courtesy of the firm of William Sellers & Co., for whose benefit and at whose cost they were primarily made.

In conclusion, it should perhaps be stated, to avoid the possibility of misunderstanding, that molecular annealing of cold cast iron by successive slight shocks differs from annealing by heat, in that it has no power to change the condition of carbon in the casting or to alter the chemical constitution in any way; all that is claimed is that every iron casting when first made is under a condition of strain, due to difference in the rate of cooling of the metal near the surface, and that nearer the centre, and also to difference of section; that it is possible, and practicable, to relieve these strains by tapping repeatedly the casting, thus permitting the individual metallic particles to re-arrange themselves, and assume a new condition of molecular equilibrium.

The large number of tests made and the remarkable uniformity of results obtained permits me to make these statements with full confidence that their repetition, even under less favorable conditions for accurate observation than I have enjoyed, will serve to convince others of their correctness, and perhaps to establish a new law of physics of cast iron.

A few practical deductions of universal application may be drawn from these observations:

1. Castings, such as hammer frames, housings for rolls, cast iron mortars or guns, which are to be subjected to severe blows or strains in actual use, should never be suddenly tested to anything approaching the severity of intended service.

Quantitative tests made upon the impact machine prove that the molecules of cast iron rearrange themselves under reasonably few shocks, so that it is perfectly practicable to molecularly anneal such castings when cold. Pulleys, and indeed all castings, are subjected in every-day service to this process of molecular annealing, and old castings are, therefore, more reliable than new ones, unless misused.

It is not impossible that the same law applies to steel castings, and, perhaps, to all metal castings, and in testing new guns each preliminary small charge of explosive material, subjecting the castings to comparatively moderate shocks, enables the gun to relieve itself of internal strains, and eventually to withstand with safety shocks which would have destroyed it without this precautionary measure. This, however, is mere theory and must not carry the weight of the arguments regarding cast iron, which are clinched by a thousand actual tests.

2. Strong iron castings, and castings of irregular section have greater initial strains than soft iron castings, or castings of comparatively uniform section, and it is, therefore, more important to subject such castings to gradually increasing shocks, until the strains are relieved by the movement and rearrangement of the molecules.

TABLE II.—Results of tests with Impact Testing Machine of cast-iron bars. (Bars marked A cleaned with a wire brush. Bars marked B " molecularly annealed.") (Weight of drop, 14 pounds);

		Fracture.	
A, ...	1 drop of 13 inches broke the bar, ...	Open	Grain
B, ...	8 drops “ 13 “ “ “ “	“	“
A, ...	2 “ “ 14 “ “ “ “	“	“
B, ...	9 “ “ 14 “ “ “ “	“	“
A, ...	2 “ “ 14 “ “ “ “	“	“
B, ...	14 “ “ 14 “ “ “ “	“	“
A, ...	2 “ “ 15 “ “ “ “	“	“
B, ...	15 “ “ 15 “ “ “ “	“	“
A, ...	3 “ “ 15 “ “ “ “	“	“
B, ...	8 “ “ 15 “ “ “ “	“	“
A, ...	2 “ “ 15 “ “ “ “	“	“
B, ...	7 “ “ 15 “ “ “ “	“	“
A, ...	3 “ “ 13 “ “ “ “	Close	“
B, ...	4 “ “ 15 “ “ “ “	“	“
A	2 “ “ 13 “ “ “ “	“	“
B, ...	10 “ “ 13 “ 5 of 15 inches, 5 of 17 inches, 3 of 18 inches, broke the bar, .	“	“
A, ...	1 drop of 14 inches broke the bar, ...	Open	“
B, ...	20 drops of 13 inches and 3 of 14 inches, broke the bar, ...	“	“
A, ...	3 drops of 13 inches broke the bar, ...	Close	“
B, ...	15 “ “ 14 “ “ “ “	“	“
A, ...	8 “ “ 12 “ “ “ “ . . .	“	“
B, ...	50 drops of 12 inches, and 10 drops of 15 failed to break the bar.		

NOTE.—The last bar, after withstanding these blows, was broken upon the transverse testing machine at a strain of 2,975 pounds.

The tables appended hereto show the results of tests for transverse strength of test bars of different sections and widely different grades of iron which have been subjected to this process of molecular annealing, and also tests made upon the impact machine with test bars cast in the same molds.

Desiring to avoid unnecessary duplication of figures, a few individual tests only are here tabulated; but they represent the average of probably a thousand records.

The largest comparative gain, shown in the first table, in transverse strength, of companion bars of 1-inch section, is 525 pounds (see last line), or very nearly nineteen per cent.

It is evident, even without plotting all the tests, that they would show a gradually ascending curve having direct relation, first, to the character of the alloy of iron; second, to the number of blows given, up to the point where strain is relieved, beyond which an increased number of blows does not increase the strength of the bar. Furthermore, it may be noted that the tests with the impact machine prove the existence of a similar law in relation to the ability to resist sudden and severe shocks.

Similar observations apply to the tests recorded of $\frac{1}{2}$-inch and 2-inch bars. All of the 2-inch bars were broken upon the testing machine of Messrs. A. Whitney & Sons by their operator, who was at first ignorant of the object of the tests. Subsequently similar tests were made by that firm with their car-wheel iron, and identical results were obtained by them.

TABLE III.—Results of test of 2-inch cast-iron bars upon A. Whitney & Son's Testing Machine. (Bars marked A cleaned with a wire brush. Bars marked B molecularly annealed):

	Breaking strain lbs.	Grade of Iron
A,	20,400	Close grain
B,	21,600	" "
A,	13,600	Open "
B,	15,800	" "
A,	14,000	" "
B,	14,800	" "

Other experiments have suggested themselves in the course of this investigation, and my paper, therefore, is not presented as an exhaustive, but as a tentative treatment of this interesting, and, I believe, novel line of research, which is not devoid even in its present stage of some practical application.

PICKINGS FROM THE PRESS

THE SPECIFIC GRAVITY OF CEMENT.

WITHIN the last few years the determination of the specific gravity of hydraulic cements has passed out of the category of methods of assay to be occasionally used, into that of modes of testing habitually employed in the evaluation of this class of constructional material. In thus changing its status this test had to encounter the rivalry of one already well established, and deemed preferable by many, viz., the determination of the weight per bushel.

One great factor in the contest between the two methods consisted in the increase in fineness of all ordinary cements, arising both from the growing stringency of the demands of foreign markets and from the more exacting requirements of engineers in this country. This factor was wholly on the side of the determination of specific gravity instead of weight per bushel. Consumers were quick to recognize that a finely ground cement necessarily weighed less, other things being equal, than one which was coarsely ground, and, moreover, that it was not easy to make a satisfactory sliding scale, and form a standard of relation between fineness and weight per bushel. At this juncture, appreciation of the fact that the specific gravity of a cement is unaffected by the degree of fineness, led to a general abandonment of the use of weight per bushel, and to the adoption of the determination of specific gravity in its place. The upshot at the present time is that the specific gravity of a cement is generally conceded to give all the information concerning the quality of a cement which was afforded by the former method of testing, and in addition to give certain other indications of its own. When properly carried out, the experimental error is but small, and the results obtained require fewer corrections in order to afford a consistent meaning.

Whether the causes just sketched have been at work in France as well as here, is uncertain, but a similar effect is at least apparent. In one of the monumental volumes recently issued by the Commission des Methodes d'Essai des Materiaux de Construction, the whole subject is discussed with much lucidity. It appears that our neighbors consider themselves behind their competitors in the adoption of the specific gravity test, and are anxious to bring it into regular and intelligent use. To this end the requisite precautions are described, and may be found of value to those interested in cement.

The usual method of taking the specific gravity of cement differs in no essential respect from that commonly adopted for other substances; it is in the details of working necessitated by the nature of the material that special care is required. In all cases a known weight of cement is allowed to displace a measured volume of some liquid; but the variations of manipulation designed to make the operation accurate, simple, and rapid are numerous. In the first place, it is obvious that the liquid displaced by the cement cannot well be water, inasmuch as hydration of the cement would occur during the process, and a consequent alteration of its volume would result. The use of some liquid free from water, and neither very volatile nor hygroscopic, must therefore be adopted. Those mentioned by the French Commission are benzine—the coal tar product commonly called benzole—and petroleum spirit. Both are somewhat more volatile than is desirable, and spirit of turpentine, thoroughly dried by standing over quicklime, is probably preferable to either. Absolute alcohol is much too hygroscopic for convenient use, and kerosene—ordinary "paraffine-oil" for domestic lighting—is apt to contain light fractions which are open to the same objection as that urged in the use of petroleum spirit. Whatever liquid be ultimately chosen, it must be mobile enough to allow the ready escape of bubbles of air imprisoned in the cement.

With regard to the degree of accuracy with which the specific gravity of a cement must be determined in order to yield useful results, it may be said that very rough figures will suffice to relegate a product, of which the origin and history are unknown, into its proper class. Thus a specific gravity of about 3.15 at once stamps the cement possessing it as a true Portland cement. In like manner, blast furnace slag has a mean specific gravity of 2.60, and admixture of any serious proportion with a true Portland cement would be at once indicated by the low specific gravity of the product.

It is interesting to note that, as stated above, the application of the specific gravity test is neither so common nor so well understood in France as it is here. The very committee appointed to report on the matter regrets that the determination of the specific gravity cannot be used for detecting an under-burnt cement, while in the same sentence quoting figures which easily suffice for that purpose. A wellburnt cement was found to have a specific gravity of 3.154, and one which was under-burnt gave the figure 3.108. Seeing that with nothing more than ordinary skill and care the specific gravity of a cement can be determined with accuracy to 0.005, and that the difference here noted is nearly ten times as great, it is evident that the conclusion of the committee is invalid. As a matter of practical fact, the determination of the specific gravity of cement is used freely in this country to distinguish between well and under-burnt cements. With obsolete apparatus and clumsy manipulation, the records were doubtless inconveniently close; but with modern apparatus and trained hands, the feat is of the simplest.

Attention is very properly directed to the influence of water and carbonic acid absorbed by the cement from the air upon its specific gravity. A single per cent. will make a sensible difference, and judgment of the exact meaning of the specific gravity of a given sample is much aided by having record to this effect. The change produced by aeration is in the direction of lightening the cement, the reason being that the hydrated and carbonated compounds, formed on exposure to air, are of lower specific gravity than the cement fully clinkered and free from all moisture as it comes from the kiln. An account is given of the commoner forms of apparatus used for the determination of specific gravity of cement, but as these are well known, a description in these columns would be superfluous.

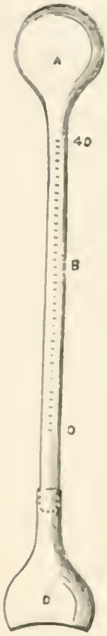

FIG. 1.

Two forms of recent design, and both of French origin, merit special notice. The first is one due to M. Candlot, and is shown in Fig. 1. It consists of a flask, C, into the neck of which is ground the glass tube, B, bearing a bulb, A, at its upper end. The apparatus is used in the following way:

Benzine, or other appropriate liquid, is poured into the bulb, A, separated altogether with the tube from the flask, C, in such quantity that on re-connecting the apparatus and bringing it into its normal position the flask, C, is filled, and the liquid stands at or about zero on the graduated tube. The height of column is read, the apparatus is again inverted, and the benzine allowed to flow into the bulb, A, so as to permit of the removal of C and the introduction of a known weight of cement. The tube and flask are joined once more, and the whole well shaken, to expel air-bubbles from the cement and to cause it to displace its true volume of liquid. The height now reached by the liquid in the graduated tube is the measure of the volume of a known weight of cement.

Before the second reading it is, of course, necessary to bring the whole apparatus to the same temperature as that which it had at the time of the first reading. Immersion in a water-bath allows of this adjustment. The process thus performed is less operose than it sounds, and gives fairly exact results. Expulsion of air-bubbles is tolerably easy when dealing with Portland cement, which is not unusually finely ground, but with hydraulic limes it is difficult.

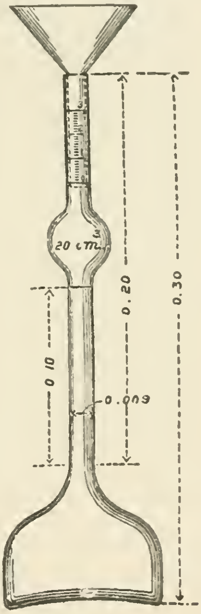

FIG. 2.

The second apparatus is one designed by M. H. Le Chatelier, and is altogether better than the foregoing. It has been officially adopted by the Commission. As shown in Fig. 2, it consists of a flask of a capacity of about 120 cubic centimetres, and having a neck some 20 centimetres in length, half-way up which is a bulb having a capacity of 20 cubic centimetres. Above the bulb the tube is graduated for a length corresponding with a capacity of 3 cubic centimetres, the divisions being 0.1 cubic centimetre. The diameter of the tube is about 9 mm.—say one-third inch. The instrument is used in the following way:

The flask is filled with benzine to the mark just below the bulb, and 64 grammes of the cement to be tested are gradually introduced through the funnel shown at the tube. By using a funnel reaching nearly to the upper part of the bulb, risk of the cement blocking the upper narrow graduated tube is avoided. As the level of the benzine rises to the lowest point of the graduations the cement is introduced cautiously, little by little, until the first graduation is reached. The volume of the cement in the flask is then 20 cubic centimetres, and its weight is ascertained by deducting that, or the portion left, from the original quantity of 64 grammes. Conversely, the whole quantity can be inserted, and the volume over and above 20 cubic centimetres read off on the upper graduated tube.

The figures quoted are for cement such as true Portland, with a specific gravity greater than 3.0. For other hydraulic cements of lower specific gravity smaller weights can be taken. The flask is kept in a vessel of water throughout the operation, and errors due to fluctuations of temperature are thus avoided. It is stated that air-bubbles are completely expelled from the cement as it flows down the long tube below the bulb, without need arising for shaking the apparatus.

As far as can be judged without actual use, the little instrument is well devised, but its readings would be scarcely close enough for exact work. Thus, each division—0.1 cubic centimetre—on the graduated tube corresponds in the case of Portland cement with a difference of specific gravity of 0.015, a possible error which is unduly great. It is certainly doubtful whether the absence of air-bubbles can be assured by spontaneous passage of the cement down the column of liquid in the tube below the bulb. Cement is particularly tenacious of its enclosed air, and will carry such air down through a long column of liquid with surprising ease. Nothing but diligent tapping and shaking will dislodge bubbles thus enclosed, and eliminate the air due to their volume being credited to the cement.

Apart from these details—which are matters on which friendly criticisms may be offered without imperiling international good-will—the report is altogether clear and excellent, and goes to prove that if there has been any delay on the part of French experts to adopt a method of testing which is now generally approved in this country, that delay is in a fair way to be forgotten by our appreciation of the keenness and clarity with which they have now set themselves to decide upon and introduce a trustworthy standard method and apparatus.—*The Engineer* (London).

RECENT BOILER-PLATE TESTS.

Some interesting results have been obtained by the Paxton Rolling Mills, of Harrisburg, Pa., on tests of boiler-plates for 20 Russian locomotives now building at the Baldwin Locomotive Works. The steel had to show a tensile strength of 35 to 42 kilos. per square millimetre (about 50,000 to 60,000 pounds per square inch), and an elongation in 8 inches of 25 per cent., both longitudinal and transverse. With the exception of 20 plates 5/8 by 87 inches wide, the material varied from 1/2 to 3/4 inch thick by 74 inches wide and under. Of the 104 plates rolled, three failed in tensile and one on gauge. In elongation the remaining 100 plates averaged 27.46 per cent. in the longitudinal direction, and 27.90 per cent. in the transverse—the latter result not generally looked for. All the steel slabs were furnished by the Pennsylvania Steel Company, made in open hearth basic furnaces, and showed an average analysis as follows: Carbon, 0.165; phosphorus, 0.014; manganese, 0.37, and sulphur, 0.27.—*The Iron Trade Review.*

TENSILE TESTS OF CAST STEEL.

Below is published a table showing the result of tensile tests of fifteen specimens of cast steel. These castings were made by the American Steel Casting Company, of Thurlow, Pa., for use in the Buffington-Crozier disappearing carriages, being built for the Ordnance Department of the United States Army. The results would be remarkable for the best forgings, and for steel castings they are considered by experts as really extraordinary. The figures published are duplicates of those which appear on the report of Captain D. A. Lyle, Ordnance Department, United States Army; and Captain Lyle, in signing the report, offers his congratulations. The results here shown cover castings produced from five different heats, indicating remarkable uniformity. The length of stem of the test piece was two inches, and in each case the fracture is noted as silky, and all of the specimens were accepted.

Steel Castings made by the American Steel Casting Company, for the Ordnance Department, U. S. A.—Tensile tests.

Elastic limit. Pounds per square inch.	Tensile strength. Pounds per square inch.	Elongation after rupture. Per cent.	Reduction of area after rupture. Per cent.
30,000	67,000	28.8	46.3
32,000	68,500	29.0	47.8
30,500	67,000	30.6	52.8
30,500	70,500	28.8	41.0
33.500	72,500	27.2	42.5
30,500	65,500	29.8	44.9
30,000	65,000	30.5	54.1
32,000	69,500	27.0	48.6
29,000	65,000	26.0	50.0
30,000	65,000	30.2	51.1
30,000	68,500	28.3	42.2
30,000	65,500	26.0	50 9
33,500	68,500	34.3	43.7
29,500	66,500	29.2	48.0
32,500	69,000	28.0	41.9

—*The Railway Review.*

THE HOLDING POWER OF LAG-SCREWS.

Some time ago I made a few experiments on the holding power of lag-screws, the result of which is given below. The holes were bored by a common carpenter's bit in 8-inch square logs, and the screws put in same as would be in common practice, and they were pulled out by the use of an Olsen testing-machine:

Diameter of screw	Diameter of bit.	Length of thread screwed into the wood.	Kind of wood.	The load at which screw pulled out.
7/8 in.	5/8 in	3 in.	Spruce	5,000 lbs.
7/8 in.	11/16 in.	3 in.	"	5,900 lbs.
7/8 in	3/4 in.	3 in.	"	6,000 lbs.
7/8 in.	3/4 in.	5 in.	"	9,000 lbs.
7/8 in.	3/4 in.	5 in.	Chestnut	9,500 lbs.
3/4 in	5/8 in.	4½ in.	Spruce	7,000 lbs.
3/4 in	5/8 in.	4½ in.	Pitch pine	8,300 lbs.
5/8 in.	1/2 in.	4 in.	Spruce	6.000 lbs.
1/2 in.	3/8 in.	3½ in.	"	3,500 lbs.
3/8 in.	5/16 in.	2 in.	"	1,900 lbs.
1/4 in.	3/16 in.	1 in.	"	700 lbs.

The experiment seems to indicate that there is no advantage in using too small a bit when boring holes for lag-screws. For instance, the 7/8 screw required fully as much force to pull out from a 3/4 hole as it would take to pull out of a 5/8 hole, although it is a great deal easier to put the screw in after a 3/4 bit than it is after a 5/8 bit, and it is certainly work spent in the wrong direction to use a bit smaller than the core of the screw.

By splitting the block and examining the wood around the screws it will be found that when too small bits are used the fibres in the wood around the screws are crushed and destroyed, but when the right size bit is used the thread in the wood around the screw looks clean-cut, the texture of the fibres is pressed, and the fit in the wood on the screw resembles the appearance of a nut on a bolt.

When the 7/8 screw was screwed into a 3/4 hole its full length of thread, or 5 inches, it required a force of 9,000 pounds to pull it out; therefore it is safe enough for any temporary job under a steady stress to lift one ton in a 7/8 lag-screw, as this gives about 4 as factor of safety in pulling out of the wood, and there is no danger of pulling off the screw itself, because at the place of the core where it could break it is about inch in diameter = 0.37 square inch area.

Assuming ultimate tensile strength to be 50,000 pounds per square inch, the breaking load would be 50,000 × 0.37 = 18,500 pounds; thus there is no danger at all of the screw itself breaking for a load of a ton.—*P. Lobben in American Machinist.*

MORTARS AFFECTED BY FREEZING.

It appears to be ascertained as a fact, based on more than six thousand recorded results, that Portland cement mortar suffers no surface disintegration under any condition of freezing, but that in most cases its strength is reduced, in some cases by as much as 40 per cent. Rosendale cement is disintegrated when exposed to frost while setting, and its cohesion may be entirely destroyed by immersion in water, which becomes frozen around it. Salt water prevents this disintegration to a large extent, but seems to have an injurious effect upon the strength, and the cement below the disintegrated surface is stated to be increased in strength when the Rosendale cement is used. A mixture of a natural rock cement and of Portland cement is found to give very satisfactory results, as its surface does not disintegrate, and its strength is increased by the freezing. Portland cement is injured less proportionately as the percentage of the cement in the samples is reduced. Again, though lime mortar is ruined by alternate thawing and freezing, fairly good results may be looked for in the case of brick masonry when the mortar is kept frozen for some time after laying.—*The Railway Review.*

Engineers know that the strength of wrought iron at 60° and 320° is practically constant, while at 30° the strength was greater; but until Professor Dewar's recent researches they could never have conceived that when immersed in liquid air at a temperature of −320° the strength of iron wire would be raised from thirty-four tons to sixty-two tons per square inch. The chemical constituents of iron and steel do not change, but the molecular arrangement and intercrystalline cohesion must change, and it is to mathematical investigation and laboratory work, rather than to practical engineering that we must look for an elucidation of the process.—*Engineering Mechanics.*

LETTERS TO THE EDITOR.

This department is set aside as an open door for communications upon all subjects pertaining to the physical properties of the materials of construction. We solicit letters from the colleges, private and governmental laboratories, both at home and abroad, and from all those interested in the field which we represent. It is desired that this department shall be the means of bringing forth and circulating amongst engineers and architects the knowledge gained in these various laboratories. And we shall hope to have it well filled with testing-room kinks, and practical facts of permanent value.

PRESS PRESSURES.

Editor Digest:—In testing dies which are mounted in punching, forming, and coining presses, it is often desirable to know the pressure exerted through them, not only at its maximum point, but at other stages during the descent of the ram. For this, as far as the writer is aware, no special device has ever been built, the few experimenters in this line having had recourse to a pair of dies mounted temporarily in an ordinary testing-machine.

It is much to be desired that a practical "testing-bolster" should be contrived which could be placed upon the bed of any press, and upon which ordinary dies could be mounted. For the majority of the work a device in the form of a flat plate, not more than four inches thick, one foot wide from front to back, and of any reasonable length between one and four feet, would be immensely useful. It should have a range for measuring presses from, say, 100 to 200,000 pounds, and should preferably be a recording instrument, capable of making a chart similar to the diagram of a steam-engine cylinder, the ordinates of the curve representing the pressures, and the abscissæ the time, or, what amounts to the same thing, the amount of ram-descent during the time in which actual work is done.

The writer has contrived several methods for accomplishing the above purpose, but has never yet found any which seemed as if it would satisfactorily (and *cheaply*) meet all the conditions. The actual building of the device is therefore in abeyance, for the present, unless indeed somebody else has taken it up. The chief difficulties in the way are the small available space and the necessity of weighing so heavy and so greatly varying a pressure anywhere over a broad, flat space. Were it balanced in the centre, the task would be easier, as it also would for a small range of pressures.

OBERLIN SMITH.

BRIDGETON, N. J.

LENGTH OF REDUCED SECTION *versus* ELONGATION OF TEST SPECIMENS.

Editor Digest :—Answering your inquiry, asking the writer's opinion on the effect of lengthening the distance between the necks of test pieces for tension tests, the writer would say that the greater the distance between the necks, the larger will be the percentage of elongation in each inch of test piece after the piece has been subjected to the breaking strain.

From the number of tests made in the Physical Laboratory of the Phœnix Iron Works, the truth of this statement has been demonstrated beyond doubt.

The writer personally conducted a series of tests, in which four test pieces were cut side by side from the same plate, from three different plates, making in all twelve pieces. One piece from each plate was necked to the length of 2″, one piece from each plate to 8″, and one to 12″, while the fourth piece from each plate was planed to the width of the necked section in the other test pieces. After breaking, it was developed that the piece 2″ long had stretched on an average of about 36 per cent., while the 2″ adjacent to the fracture in the 8″ long piece had stretched fully 37 per cent., in the 12″ piece the 2″ section had stretched over 38 per cent., and in the piece which had not been necked the elongation in a similar length had been over 39 per cent. It was also noticed that the elongation in 8″ of the two long pieces was proportionately more than in the pieces which had been necked to 8″.

At first sight this is paradoxical, but on reflection it seems perfectly clear that the molecules of the long sections have more time to adjust themselves to the ever-changing conditions of the test pieces while being pulled, while the shorter pieces, being broken in so much less time, have very much less time to accommodate themselves to the conditions.

I do not know that these results have developed anything which has not been known, but in view of the important relation existing between the percentage of elongation and the ultimate strength, they are not only important, but interesting as showing the effect of the length of the piece upon the elongation, as developed by testing in a standard testing machine.

It is a general rule that soft steel will develop a much greater elongation than steel of a higher tensile strength, and it therefore follows that the better of two steels is the one that will show the higher ultimate, if the percentage of elongation is the same as in the softer steel; and, similarly, that if the ultimate strength of two steels is the same, that which shows the greater elongation is the better.

Nearly all specifications are based upon the results of previous tests, and it is manifestly unfair to the manufacturer to expect steel to develop in a necked section 8 inches long the same elongation that was at some previous time developed in 8 inches of a section 12 inches long. On the other hand, if a specification has been based upon the elongation as developed in a test specimen necked to a length of 8 inches, the results obtained from a section 12 inches long, or longer, are clearly unreliable for comparison.

As existing specifications have, for a large part, been written by theoretical but impractical engineers, and are largely influenced by personal bias and opinion, and do not represent the thought of the persons best able to define what should be required in steel or iron for its various uses, viz.: the manufacturers; the writer would suggest that the editor of the DIGEST should take up the question now being agitated by several of our most prominent steel manufacturers, and urge the adoption of a uniform specification for quality of material in a convention in which the manufacturer should be represented. The question of length of test piece should be definitely settled by such a convention, for by this means only can uniformity of results be obtained.

ED. HAUPT.

PHOENIXVILLE, PA.

NOTES AND COMMENTS.

ENGINEERS all over the country will be interested in learning of the discovery of a new method of conducting tests when the strength of the specimen to be tested exceeds the capacity of an available machine. Since the strength of a material is in direct proportion to its area, and the area is in direct proportion to the diameter, it is hardly the work of a moment to ascertain the approximate number of square inches in a test specimen. We say "approximate" because the exact ratio of the diameter of a circle to its circumference is not known, although it is believed that the ancient Egyptian philosophers were in possession of the secret. Ahmes, a scribe of King Ra-a us, in his *Papyrus Rhind*—the oldest mathematical book in the world—gives a transcript of a treatise written about 2,500 years B. C., in which was a rule for finding the area of a circle. Another solution was claimed by Hippocrates, the geometrican of Chios, 500 B. C. The Babylonians, also, had a rule, but it was not until Euler introduced the symbol π to represent the ratio of the circumference of a circle to its diameter, and Archimedes proved it to be less than $3\frac{1}{7}$ and greater than $3\frac{10}{71}$, that the ratio of $3.1416+$ was accepted, and the problem brought within the scope of the ordinary machine shop. But out of the hundreds of known rules for squaring the circle, there are none quite so startling as the one recently evolved by a nineteenth-century engineer and inspector in the employ of one of the prominent English Steamship Insurance Companies, who, having occasion to test the tensile strength of a $1\frac{3}{4}$ inch chain cable when the largest available testing machine would only pull $1\frac{1}{2}$ inch diameter, first broke a one-inch chain and then a three-quarter inch chain, added the results together, and handed in his report.

If the resolution providing for an investigation into the Bureau of Ordnance of the Navy, recently introduced before the Senate by Senator Chandler, and which has excited such interest and comment in navy circles, is accepted, and the investigation conducted with the thoroughness the resolution calls for, many facts are certain to come to light which, it is believed, will seriously effect the integrity of the Navy Department. In Washington it is current talk that while every large railway corporation and industry interested in the purchase of material by contract only accept such after rigid inspection by high-class experts, the Navy Department has, for years past, assigned to this duty ensigns and lieutenants with no practical knowledge of either the materials or their manufacture. In our own experience with Government Inspectors, both with experienced men and those just assigned to the duty, we have yet to find one who, though not possessed of an accurate knowledge of the manufacture of the materials, is so lacking in common intelligence as to make such an exhibition of his low-classness as reported in the test of chain cable cited above, which was conducted by one of the so called high-class experts.

A correspondent writes us that he is very much pleased with the initial number of THE DIGEST, and assures us that the publication will meet with success, but suggests that we omit all such unscientific matter as appears upon page sixteen. While we feel that his criticism is entirely fair, and are very grateful for the friendly spirit in which it is given, we think he is rather hard on one of our tender years, and should appreciate that so sudden an appearance of a Black Cat was likely to drive any poor devil of an editor to the point of making fun. And wherein lies the harm? Surely it is strengthening to one's nerves to indulge in a bit of innocent foolery as an appetizer before swallowing something heavy. It is told of Abraham Lincoln that he frequently interspersed humorous anecdotes while discussing the gravest affairs of State. With this example before us, we feel exonorated for introducing matter which, to the serious-minded, may appear frivolous and out of place.

The Fifth International Congress for the unification of the methods of testing materials of construction was held at Zurich in September, 1895. Nearly five hundred members took part in the deliberations, either by correspondence or by actual presence, six of whom were from the United States. On the third day the work of the American Society of Mechanical Engineers was fitly recognized by its representative G. C. Henning, of New York, being called to the place of honorary chairman. A large number of valuable papers were read and discussed. Professor L. de Tetmajer, of Zurich, was elected President of the Association for the year 1896 and 1897, and an executive committee, composed of Professor Belelubski, of St. Petersburg; Councillor Berger, of Vienna; Professor Martens, of Berlin, and Baron Rochemont, of Paris, was appointed. Authorities on the subject of testing and organized societies are admitted to the Association on their application; others must be proposed in writing by two members. Each member agrees to contribute in proportion to his means to advance the aims of the Association. Propositions for membership should be directed to the President. An annual fee of five francs, four marks, or one dollar, is paid by each member, and he receives the journal of the Association at a reduced price. The affairs of the Association are managed by the president and executive committee, aided by an advisory committee of delegates to the Congresses which are held every two years. A movement is on foot to issue an international review which will doubtless appear as a part of the journal of the Association. The Sixth Congress will be held at Stockholm in 1897, and the Seventh at Paris in 1900. It is to be hoped that the number of American members of the Association may be largely increased, so that a full presentation of American methods of testing may be made at those Congresses. Uniformity in testing is necessary for the purposes of comparison; much good work has been already done in this direction by the International Association, and much more will result from its future deliberations.

* * *

All practical steel plate and rolling-mill owners will join us in entering our protest against the adoption of a standard test specimen of the form recommended in the amendments recently submitted by the committee of the American Steel Manufacturers to the Board of Supervising Inspectors of Steam Vessels at Washington. The specifications provide that the test-pieces shall be prepared in the form shown in Fig. 1, which, every practical engineer will see at a glance, is a very difficult and expensive shape to make. When it is considered that some of the large mills pull their tests at the rate of sixty per hour on a single testing machine, it will be appreciated that the cost of preparing the specimens is a very important item in the expense of maintaining a laboratory. Sixty specimens per hour is, we think, far too fast to obtain reliable results, giving too high a tensile strength and destroying the elongation, but to be able to pull even half this number per hour, requires the use of the most modern appliances for preparing the specimens. Before the introduction of special tools for this purpose, it was not unusual to see as many as six shapers running to supply one testing-machine. Test pieces prepared on a shaper have both edges parallel throughout their length, but these, in turn, as shown by Mr. Edward Haupt, of the Phœnix Iron Co., have too great an elongation. In later practice various other more rapid methods have been tried, among which are the Newton Saw and the Ingersoll Planer. The saw was never destined to set rivers on fire, and soon dropped into oblivion, while the Ingersoll Planer, though a large and powerful milling machine, well adapted to a wide range of usefulness and capable of rapid work, possesses the disadvantage of only milling one side of a row of specimens at a time. The newer machines are designed on the rotary planer principle, and finish both sides of a row of test pieces simultaneously. The machines are fitted with two heads, each carrying from eight to twelve tools. The shape of these tools fix, of course, the shape and size of the fillet in the test specimens, and since the tools, to obtain a smooth finish in the test pieces, must be dead in line, it is necessary to grind them after they are set in the heads. By using tools ground to form a specimen the shape of Fig. 2, this grinding is reduced to a comparatively simple operation. They can, however, be more readily ground to give the form shown in Figs. 3 and 4, but to produce the test piece shown in Fig. 1, requires the use of an axle-mill four inches in diameter, and the slow process of feeding the cutter by hand until it reaches the required depth, this tedious

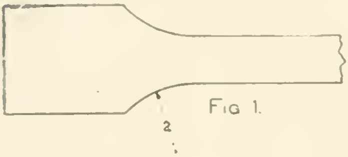

Fig 1.

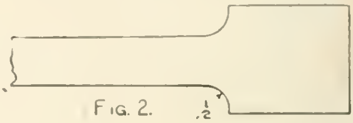

Fig. 2.

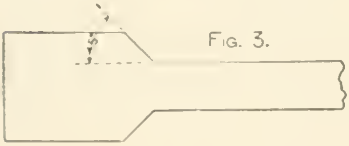

Fig. 3.

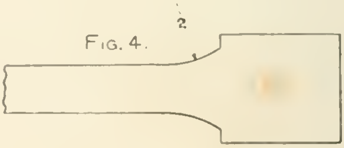

Fig. 4.

task only being obviated by the additional expense of a special grinding machine to round the corners of the cutter, so as to permit cross-milling. Why, in these times of systematic inspection of material by "high-class experts," manufacturers should be obliged to incur the heavy expense of preparing test specimens in the form proposed by the committee, when other and cheaper forms give precisely the same results, and curtail the tax on the time and patience of the Government Inspectors who are obliged to remain idle while the test pieces are being prepared, is, to us, an unexplainable mystery.

In another part of this issue appears a report on a series of tests on paving bricks to determine the compressional strength and the amount of absorption. Considering the immense growth of the paving-brick industry during the last ten years, it is important that the testing laboratories of the country should devote some attention to the qualifications of a first-class paving brick. The engineering societies should prescribe a standard method of testing paving bricks, for at the present time the methods are so at variance that we have no means of comparing the relative merits of paving material. The most important tests that can be made are the tests for compressional strength and the amount of moisture absorbed ; the former gives us a definite notion of the brittleness and elasticity, as well as the compressional strength ; the latter enables us to select a brick that will not disintegrate in freezing climates. The record of tests presented by Professor Anderson includes twelve of the most important and reliable paving bricks made in this country, and the illustrations of the fractures form an important feature of the article, for by these fractures we are able to determine, to a large extent, the homogeneity of the paver, and by this means the care with which the material is ground and worked will be apparent.

In a recent letter to the *Engineering News*, Booth, Garrett & Blair give the following rule for determining the proper proportion of water in mortar mixtures, which, they say, has been adopted in their laboratory with entirely satisfactory results. First determine by pat tests the proper percentage of water for the neat cement, then reckon at 7 per cent. the amount of water required for the sand. Thus, if the neat cement takes 25 per cent. of water, the proper amount for a three to one mortar would be as follows:

1 part cement at 25 per cent.,	.25
3 parts sand at 7 per cent.,	.21
4 at 11½ per cent.,	.46

Or for a two to one mortar of the same cement as follows:

1 part cement at 25 per cent.,	.25
2 parts sand at 7 per cent.,	.14
3 at 13 per cent.,	.39

This rule gives proportions of water which are entirely satisfactory for ordinary commercial mortar sands; a little less can be used with standard test sand. For rammed work we are confident these proportions should not be exceeded; if they are, the mortar will be "sloppy." For work which is laid with a trowel, more water is advantageous. The rule is also quite satisfactory for concrete, if the stones are moistened before they are added to the mortar.

The history of the designing and constructing for the United States Government, by Mr. A. H. Emery, of the famous *one million pound testing machine*, which has been in constant use at the Watertown Arsenal for fifteen years, is well known to physicists and engineers. The machine differs so radically in principle from all other testing machines that it has created world-wide interest, not only on account of its great capacity, but also from its extreme delicacy and sensitiveness in operating, being practically as sensible of small variations of stress when loaded to its full capacity, as when merely tested under the weight of the beam itself. When it was originally announced that friction under heavy loads was so completely neutralized that a practically frictionless testing machine resulted, the statement was received with incredulity, then with wonder, but is now accepted as a demonstrated fact. The chief objections that have been raised to this machine are the first cost and the slowness of action as compared with testing machines of the usual construction. While it is true that the design of the machine renders it, necessarily, somewhat costly to construct, and while it is also true that the Watertown machine is not as well adapted to rapid commercial work as to original scientific investigation — for which purpose it was built, these conditions are now greatly changed. Several years ago the firm of Wm. Sellers & Co., Incorporated, acquired the patent rights for the commercial manufacture of this machine, and have devoted themselves to gradually decreasing the cost and increasing the speed of operation, while scrupulously retaining the original marvelous delicacy and accuracy. Improved arrangements for rapidly clamping test pieces—preserving true alignment—so that they cannot possibly be subjected to torsional or bending strains, when a straight pull is desired, and other new mechanical devices have successfully overcome the former objections and introduced novel advantages. An idea of the possible speed of tests when the Emery machine is properly adapted to special work may be gleaned from the daily records of the Washburn & Moen Co., of Worcester, Mass., where an ordinary day's work upon their machine is 600 records of ultimate stress and elongation of wire samples, and, on busy days more than 700 separate tests have been recorded.

Until recently there appears to have been no uniform standard of tests for leather used in the manufacture of shoes and other articles required for use in the United States Government service. Each manufacturer of leather, in order to show to the purchaser the quality of his product, used various crude methods of his own, one of which was to puncture a piece, and then force his finger or some implement through the opening and tear it apart. Others would press their thumbs through the leather and note the resistance to tear—certainly "a rule-of-thumb" method. The employment of such tests as these proved, of course, entirely unsatisfactory to the officers in charge of purchasing, and led eventually to the design of a special testing-machine and the adoption of a standard, whereby uniform and comparative tests could be obtained, and all leather placed upon its relative merit. Testing machines have been applied to all kinds of material, but this is a new field and one that is destined to excite considerable interest. Every manufacturer wants to excel in the quality of his product, and when he has once attained a high grade of material he is particularly anxious to get full value for it. There is nothing so disastrous to a manufacturer as to be without a standard by which good material can be appreciated and paid for, and poor material condemned and rejected. It is of just as much importance to the manufacturer of leather to determine the quality of his output by actual tests as it is for a dealer in fluids to measure the same by the quart or gallon, or manufacturers of fabrics to measure by the yard.

The American Machinist, in its issue of February 13th, has the following to say of us, which, being the only unfavorable criticism we have seen, we reprint: "THE DIGEST OF PHYSICAL TESTS AND LABORATORY PRACTICE is the name of a new quarterly published by Frederick A. Riehlé, of Philadelphia, and is an unusually ambitious and interesting example of that class of journals that have been denominated 'House Organs,' and which are the outgrowth of a manufacturer's idea that not enough is said in the regular technical journals respecting his special line of work, and that by starting a technical journal of his own he can secure adequate treatment of the subjects he is specially interested in, and can at the same time do his own advertising more cheaply than it can be done otherwise. The scheme often looks promising, but in practice it seldom, if ever, works well. It costs nothing whatever to get really interesting matter into the best of technical journals, and matter that is not sufficiently interesting to get into them will find few readers. Though there are sound economic reasons why very few manufacturers can long continue such a publication, that does not alter the fact that the relatively few engineers who are more interested in physical tests of materials than in any other branch of work will find much to interest them in this first number of the new journal referred to, which is admirable in many respects, contains good articles on the subjects indicated, and is well gotten up mechanically, good illustrations, well printed on good paper. It is in magazine form, 6x9 inches standard, and the first number contains 86 pages." We think *The American Machinist*, as shown by its attitude at the first appearance of *Machinery*, is inclined to be the opposite of gallant in its criticisms of its contemporaries, but, like *Machinery*, we would say that "there is room for us both, neighbor." Of course, all our readers know, or at least we wish them to know, that our Publisher, Mr. Frederick A. Riehlé, is the manufacturer of the well-known Riehlé Testing Machine, to which business he has ardently devoted himself for the past thirty years, and we consider that the DIGEST is only a natural outgrowth of this train of thought. It was with no little misgiving that a venture of this kind was undertaken, but it was not done without due deliberation, and the favorable comments that the first number elicited from the many are flattering in the extreme, and far outweigh the criticisms of the few whose line of work can hardly make them competent judges of this, the newest of the sciences.

The Publisher of THE DIGEST OF PHYSICAL TESTS considers an acknowledgment due the many kind friends and substantial supporters of that magazine, and wishes to express his thanks for the large number of congratulatory letters and assurances of valuable contributions which have been received from all parts of the country. In subsequent numbers the DIGEST will contain, from time to time, valuable translations from the German and French, as it is acknowledged that the subject of testing has received far more attention abroad than in the United States. We are assured that these translations are awaited with interest.

The attendance at the annual meeting of American Institute of Mining Engineers, recently held at Pittsburg, was exceptionally large. The opening session was held on Tuesday, February 18th, which was principally taken up by speeches of welcome and the President's address. Wednesday was given over to an excursion to Homestead, where the large beam mill, the armor-plate plant, plate mill, armor-plate mill, and open-hearth plants were visited in turn, followed by a highly interesting tour through the Westinghouse Electric and Manufacturing Company's new plant at East Pittsburg, and the Edgar Thomson steel plant at Bessemer. Thursday morning and afternoon was devoted to the continuance of the discussions on the physics of cast iron, many interesting and valuable facts being brought to light. Among the contributions to the debate were C. R. Baird & Co., E. K. Landis, A. E. Outerbridge, Jr., W. R. Webster, and T. D. West. Papers were also read by H. L. Hollis, on the "Walrand-Legenisel Process;" by H. A. J. Wilkens, on the "Magnetic Separation of Non-Magnetic Material;" by R. H. Richards, on "Experiments in Sorting before Sizing;" by Thomas Robins, Jr., on "Conveying Belts and Their Uses," and by Guy R. Johnson, on "The Embreeville Estate of Tennessee." In the evening a banquet was held at the Monongahela House, in which most of the members and their guests participated. Speeches were made by Joseph D. Weeks, the retiring president, and by E. G. Spilsbury, the newly elected president. Secretary R. W. Raymond responded to the toast, "Claims;" R. H. Hunt, "Defects;" Dr. D. T. Day, "Figures;" D. Riddle, "Mines and Minds," and A. P. Burgwin, "The Law," which was, by far, the wittiest and most enjoyed speech of the evening. On Friday, the last day of the convention, the members visited the McKee Brothers' Glass Works, Jeannette; The Latrobe Steel Works, Latrobe; and the Penn Salt Co., Natrona, Pa.

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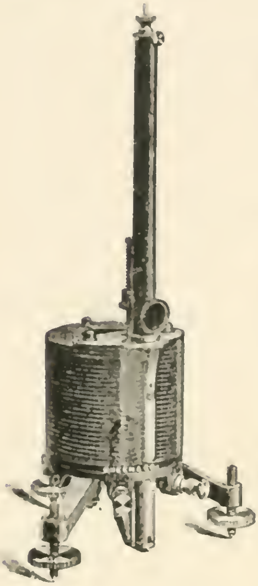

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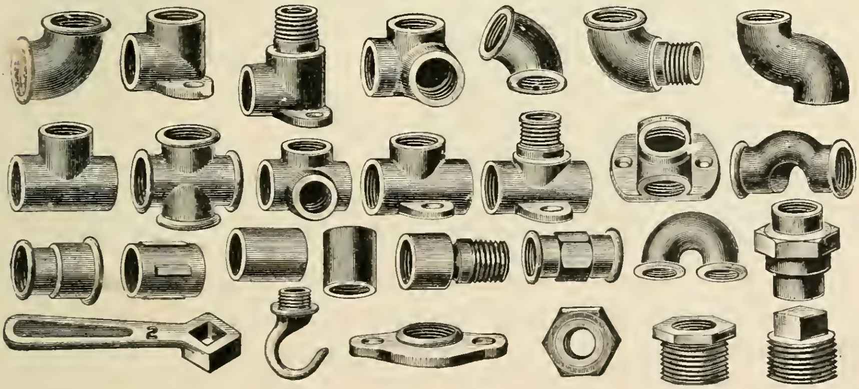

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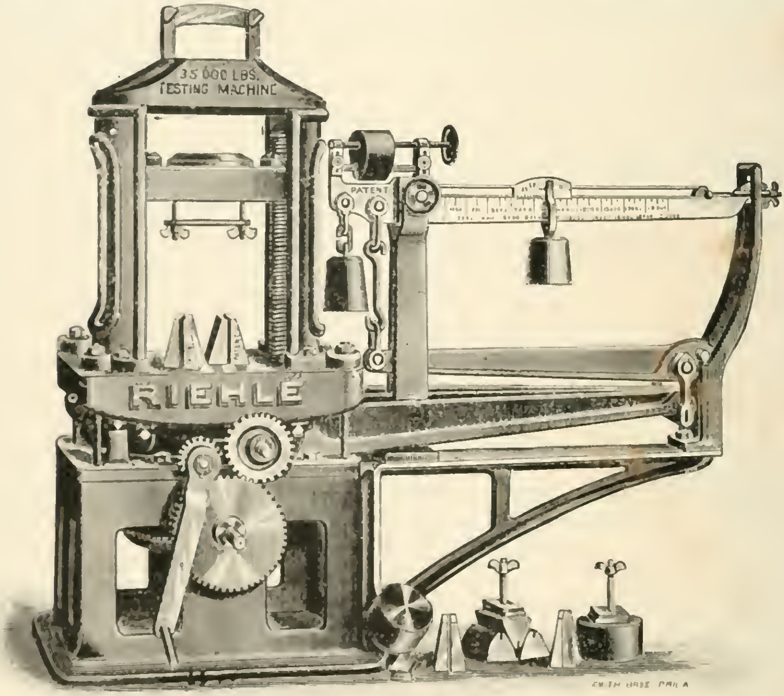

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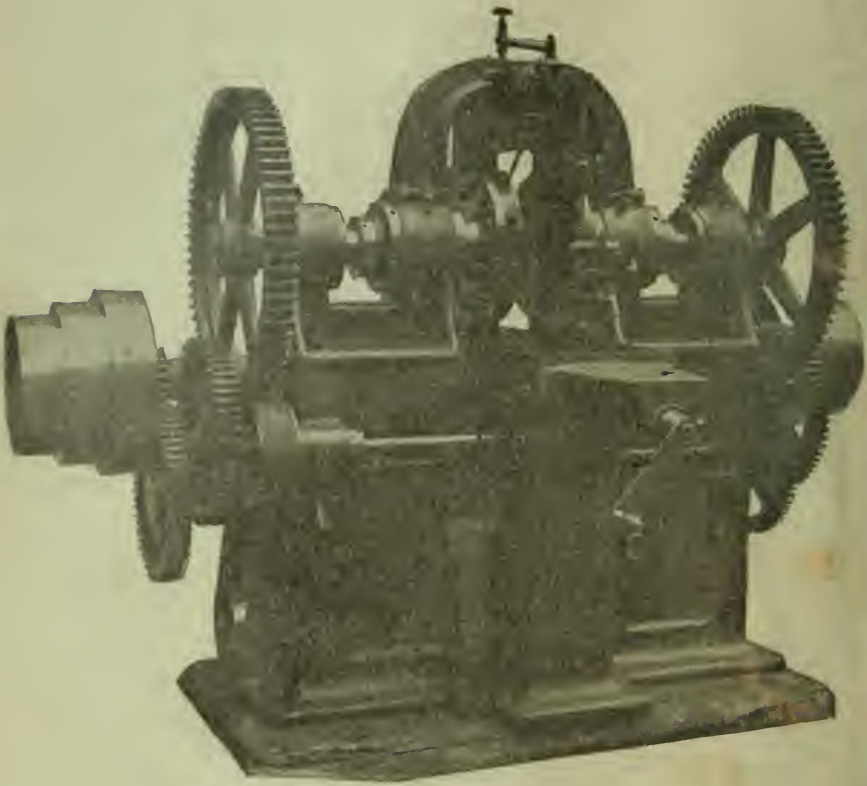

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